



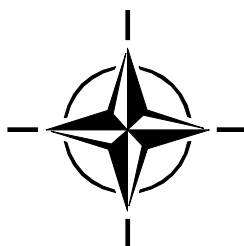
STO TECHNICAL REPORT

TR-HFM-184

# **Safe Ride Standards for Casualty Evacuation Using Unmanned Aerial Vehicles**

(Normes de transport sans danger pour l'évacuation  
des blessés par véhicules aériens sans pilote)

This Report documents the findings of Task Group HFM-184 (2009 – 2012),  
which investigated the possibility and acceptability of casualty  
evacuation using Unmanned Aerial Vehicles (UAVs).



Published December 2012

---

*Distribution and Availability on Back Cover*

DISTRIBUTION STATEMENT A. Approved for public release: distribution unlimited.





---

**STO TECHNICAL REPORT**

**TR-HFM-184**

# **Safe Ride Standards for Casualty Evacuation Using Unmanned Aerial Vehicles**

(Normes de transport sans danger pour l'évacuation  
des blessés par véhicules aériens sans pilote)

This Report documents the findings of Task Group HFM-184 (2009 – 2012),  
which investigated the possibility and acceptability of casualty  
evacuation using Unmanned Aerial Vehicles (UAVs).

NOTE: Even though the authors of this Report are American, British, German,  
and Israeli subject-matter experts in the fields of aviation, UAS, air evacuation,  
and emergency care of the trauma victim, this Report does not represent the  
formal position of any of these governments or any portion thereof. Any mention  
of trade, brand, or corporate names is for illustration or acknowledgement,  
and does not represent any recommendation of specific products.

---

# The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses

The content of this publication has been reproduced directly from material supplied by STO or the authors.

Published December 2012

Copyright © STO/NATO 2012  
All Rights Reserved

ISBN 978-92-837-0174-3

Single copies of this publication or of a part of it may be made for individual use only by those organisations or individuals in NATO Nations defined by the limitation notice printed on the front cover. The approval of the STO Information Management Systems Branch is required for more than one copy to be made or an extract included in another publication. Requests to do so should be sent to the address on the back cover.

# Table of Contents

	Page
<b>List of Figures/Tables</b>	<b>ix</b>
<b>Acknowledgements</b>	<b>x</b>
<b>HFM-184 Membership List</b>	<b>xi</b>
 <b>Executive Summary and Synthèse</b>	 <b>ES-1</b>
 <b>Chapter 1 – Introduction and Background</b>	 <b>1-1</b>
1.1 Introduction	1-1
1.2 The Utility of Aeromedical Evacuation	1-1
1.3 The Rise of UAVs	1-1
1.3.1 The Development of Cargo/Logistics UAVs	1-2
1.4 Scope of the Study	1-3
1.5 Trauma Care and the Need for Evacuation	1-4
1.6 UAVs and CASEVAC	1-5
1.7 Background to the Creation and Work of this RTG	1-5
1.8 Types of Evacuation	1-6
1.9 Possible Operational Use of UAVs for Evacuation	1-7
1.10 Objectives	1-8
1.11 Human Systems Integration	1-8
1.12 Disclaimer	1-9
1.13 Thanks	1-9
 <b>Chapter 2 – Unmanned Aircraft Systems and Enabling Technologies</b>	 <b>2-1</b>
2.1 Introduction	2-1
2.2 Potential Advantages of UAS	2-1
2.3 Representative Unmanned Aircraft Systems	2-2
2.3.1 Basic Considerations	2-2
2.3.2 Current/Developmental VTOL UAS	2-3
2.3.3 Future or Proposed VTOL UAS	2-7
2.3.4 Notional VTOL UAS Concepts	2-11
2.3.5 Enabling Technologies and Artifacts	2-12
2.3.5.1 Command and Control Architecture	2-12
2.3.5.2 Concept-Of-Operations (CONOPS)	2-12
2.3.5.3 Standards	2-12
2.3.5.4 Requirements Documents	2-13
2.3.5.5 Air Vehicles	2-13
2.3.5.6 Man-Rating	2-13
2.3.5.7 Sensors	2-13

2.3.5.8	Command and Control (C2)	2-14
2.3.5.9	Autonomy	2-14
2.3.5.10	Medical Devices for en route Care	2-14
2.3.5.11	Summary of Mission Enablers	2-14
2.3.6	Ongoing Related Efforts	2-15
2.3.6.1	Autonomous Aerial Cargo/Utility System (AACUS) Innovative Naval Prototype	2-15
2.3.6.2	Autonomous Technologies for Unmanned Aerial Systems (ATUAS) Joint Capability Technology Demonstration (JCTD)	2-15
2.3.6.3	Medium Range Multi-Purpose (MRMP) VTOL UAS	2-16
2.3.6.4	Medium Range Maritime Unmanned Aerial System (MRMUAS)	2-16
2.4	Summary	2-17

## **Chapter 3 – Current NATO Doctrine and Policy, as it Affects the Concept of Casualty Evacuation via UAVs** **3-1**

3.1	Introduction	3-1
3.2	Key NATO Doctrinal Documents	3-1
3.2.1	MC 326/3 (NATO Principles and Policies of Medical Support)	3-1
3.2.2	AJP-4.10 (B) (“Allied Joint Medical Support Doctrine” – Draft)	3-1
3.2.3	AJMEDP-2 (“Allied Joint Doctrine for Medical Evacuation”)	3-2
3.2.4	STANAG 2087 (“Medical Employment of Air Transport in the Forward Area”)	3-2
3.2.5	AMEDP-11 (“NATO Handbook on Maritime Medicine”)	3-2
3.2.6	AMEDP-38 (“Medical Aspects in the Management of a Major Incident / Mass Casualty Situation”)	3-3
3.2.7	International Humanitarian Law	3-3
3.2.8	Other Documentation	3-4
3.3	RTO Interest in UAVs	3-4
3.4	Summary	3-5

## **Chapter 4 – Potential Medical Concepts for Use of UAVs in Casualty Evacuation** **4-1**

4.1	Introduction	4-1
4.2	NATO and Coalition Operations	4-1
4.2.1	Concept Goals	4-2
4.2.2	Concept Details	4-2
4.2.3	Application and Scope	4-2
4.2.3.1	Assumptions	4-3
4.2.4	Operational Vignettes	4-3

## **Chapter 5 – Medical/Clinical Aspects/Standards for Putting People in UAVs** **5-1**

5.1	Introduction	5-1
5.2	Overarching Medical Standards	5-1
5.3	Catastrophic Bleeding	5-2
5.4	Airway Control	5-2
5.4.1	Breathing	5-3

5.5	Circulation	5-4
5.6	Disability	5-4
5.7	Exposure	5-4
5.8	Restraint and Stabilization of Spinal Injuries	5-5
5.9	MEDEVAC in Optionally Piloted Aircraft	5-5
5.10	MEDEVAC in Aircraft Designated as Unmanned Platforms	5-5
5.11	CASEVAC on UAVs	5-6
5.12	Recommended NATO UAV Flight Safety Standards	5-7

## **Chapter 6 – Safety and Other Operational Issues** **6-1**

6.1	Introduction	6-1
6.1.1	Critical Assumptions	6-1
6.1.2	Design Safety	6-1
6.1.2.1	General Requirements	6-1
6.1.2.2	Crashworthiness	6-2
6.1.2.3	Reliability	6-2
6.1.2.4	Aircraft Performance Capabilities	6-2
6.1.2.5	Environmental/Weather Safe Design Characteristics	6-2
6.1.2.6	Handling Qualities and Flight Control Laws	6-2
6.1.2.7	Intuition and Decision Making	6-2
6.1.3	Navigational Design Capability	6-3
6.1.3.1	State of the Technology – Global Positioning Systems (GPS)	6-3
6.1.3.2	Embedded-GPS and Blended Inertial Navigation Systems (INS) Systems (Abbreviated as EGIs)	6-3
6.1.4	Unmanned Aircraft Survivability in Hostile/High Threat Areas	6-3
6.1.5	Complete Autonomy, Remotely Piloted Vehicles (RPV), Human In The Loop (HITL) Systems and Sensors	6-4
6.1.5.1	Visual Sensors	6-4
6.1.5.2	Airspace Coordination and Integration into the Battle and National Airspace of an Unmanned CASEVAC System	6-4
6.1.6	The Socialization of the Concept	6-5
6.1.6.1	Relinquishing the Role	6-5
6.1.6.2	Replacing the MEDEVAC Pilot	6-5
6.1.6.3	Evolution of Unmanned CASEVAC CONOPS	6-5
6.1.6.4	Contingency Missions (The Worst Case Scenario)	6-6
6.1.6.5	Routine Mission Support	6-6
6.1.7	Technological Safe-Ride Standards for Unmanned CASEVAC – A Summary	6-6
6.1.7.1	Safety Parameters for Consideration	6-7
6.1.8	Technology Today and for the Future	6-8

## **Chapter 7 – En Route Care Medical Research, Development, Test and Evaluation (RDT&E) Gaps and Status** **7-1**

7.1	Background	7-1
7.2	Research Gaps	7-1
7.3	Research Scope	7-2

7.3.1	Description of Casualty Movement Environment and Functional Limitations	7-2
7.3.2	En Route Care Research	7-3
7.3.2.1	Safe Clinical Management and Transport of Patients with Head and Spine Injuries	7-4
7.3.3	Medical Carry-On Equipment Test and Evaluation	7-6
7.3.3.1	Background	7-6
7.3.3.2	Test Standardization	7-6
7.3.3.3	Knowledge Gaps	7-7
7.4	Summary	7-8
<b>Chapter 8 – Ethical/Legal Issues</b>		<b>8-1</b>
8.1	General	8-1
8.2	Legal Issues	8-1
8.3	Ethical Issues	8-1
<b>Chapter 9 – Current Advances in Air Evacuation and Their Applicability to UAVs</b>		<b>9-1</b>
9.1	Current Advances in Aeromedical Evacuation	9-1
9.2	CASEVAC	9-1
9.2.1	CASEVAC and MEDEVAC in Afghanistan	9-3
9.2.2	MEDEVAC – General	9-3
9.2.3	Forward Aeromedical Evacuation	9-4
9.2.3.1	Catastrophic Haemorrhage	9-4
9.2.3.2	Early Intervention – Rapid Evacuation	9-5
9.2.3.3	Hypovolaemia, Acidosis and Hypothermia	9-5
9.2.3.4	Forward AE Tasking	9-5
9.2.3.5	Potential UAV Use	9-6
<b>Chapter 10 – Summary and Recommendations to COMEDS and RTO</b>		<b>10-1</b>
10.1	Recommendations	10-3
<b>Chapter 11 – References</b>		<b>11-1</b>
11.1	Administrative/Certification/Legal/Ethical Documents	11-1
11.2	Clinical and Operational Documents	11-2
11.3	Concept/Doctrinal Documents	11-6
11.4	Engineering References/Standards	11-7
11.5	Miscellaneous	11-9
11.6	NATO Documents	11-11
11.7	Status of Development of UAS	11-12
<b>Annex A – Technical Activity Description</b>		<b>A-1</b>



## **Annex B – History and Development of Aerial Evacuation, with Specific Reference to UAV Potential Use** **B-1**

B.1	Introduction	B-1
B.2	Early History	B-2
B.3	World War I – The First Attempts	B-2
B.4	Interwar Use	B-3
B.5	World War II – Mass Evacuations and Improved Care in Flight	B-4
B.6	Continued Developments Post-WWII	B-5
B.7	Current Period, and the Relevance of UAVs to Future Evacuation Operations	B-6

## **Annex C – An Abbreviated HSI Analysis Regarding the Utilization of UAVs for Casualty Transportation** **C-1**

C.1	General Overview of HSI	C-1
C.2	Overview of the Technical Application of Human Systems Integration (HSI)	C-2
C.2.1	Analysis	C-2
C.2.2	Design and Development	C-2
C.2.3	Test and Evaluation	C-3
C.2.4	HSI Domains	C-3
C.2.4.1	Manpower	C-3
C.2.4.2	Personnel	C-3
C.2.4.3	Training	C-3
C.2.4.4	Human Factors Engineering	C-4
C.2.4.5	Survivability	C-4
C.2.4.6	Environment	C-4
C.2.4.7	Safety	C-4
C.2.4.8	Occupational Health	C-4
C.2.4.9	Habitability	C-4
C.2.4.10	Manpower	C-5
C.2.4.11	Personnel	C-5
C.2.4.12	Training	C-7
C.2.4.13	Human Factors Engineering	C-9
C.2.4.14	Survivability	C-11
C.2.4.15	Environment	C-12

## **Annex D – Thinking Outside the Box: Medical Equipment Recommendations for Future CASEVAC/MEDEVAC UAVs** **D-1**

D.1	Using UAVs to Perform Medical Missions – Medical Capabilities (Treatment and Monitoring)	D-1
D.1.1	CASEVAC Missions	D-1
D.1.2	MEDEVAC Missions	D-2
D.1.3	MEDEVAC Desirable Equipment Technical Details	D-3
D.2	Conclusion	D-4

## **Annex E – Potential Future Use of UAVs for Tactical and Strategic Medical Evacuation** **E-1**

E.1	Tactical Aeromedical Evacuation	E-1
-----	---------------------------------	-----

E.1.1	Peripheral Nerve Block Catheters	E-1
E.1.2	Staffing Differences	E-2
E.1.3	Potential Tactical UAV Use	E-2
E.2	MEDEVAC (Strategic Aeromedical Evacuation)	E-2
E.3	Summary	E-4

<b>Annex F – Key Terminology/Glossary</b>	<b>F-1</b>
---	------------

## List of Figures/Tables

<b>Figure</b>		<b>Page</b>
Figure 1-1	U.S. Navy / Gyrodyne Corporation Slide on Project “Midget”, Undated, but During the Vietnam War	1-3
Figure 2-1	Boeing Unmanned Little Bird (ULB)	2-4
Figure 2-2	Kaman KMAX	2-5
Figure 2-3	Northrop Grumman / Bell Helicopter FIRE-X	2-6
Figure 2-4	Urban Aeronautics “AirMule”	2-6
Figure 2-5	AgustaWestland RUAV	2-7
Figure 2-6	U.S. DARPA Transformer (TX) “Flying Car” / AAI	2-8
Figure 2-7	U.S. DARPA Transformer (TX) “Flying Car” / Lockheed Martin	2-8
Figure 2-8	Piasecki “Speed Hawk”	2-9
Figure 2-9	Sikorsky “Raider”	2-10
Figure 2-10	Advanced Tactics “Black Knight”	2-10
Figure 2-11	Dragonfly Pictures DP-5XT	2-11
Figure 2-12	Piasecki “Combat Medic”	2-11
Figure 4-1	NATO Safe Ride Standards CONOPS	4-3
Figure 6-1	A Proposed Operational Schema for UAV CASEVAC	6-9
<b>Table</b>		
Table 2-1	Mission Enablers Current State of the Art	2-15
Table 6-1	Safety Criteria for NATO UAS CASEVAC	6-7
Table 9-1	CASEVAC and MEDEVAC Within Afghanistan, 2009 – 2011	9-2
Table 9-2	UK-Provided Air Evacuation Within Afghanistan	9-4

## Acknowledgements

The following persons, though not formally appointed as members of this RTG, have provided important input to the RTG effort and to this report at different stages of the work, and we sincerely thank them for their contributions:

- CAPT. Richard Beane, M.D., M.P.H./T.M. – U.S. Navy Bureau of Medicine and Surgery, USA
- COL. William Butler, MD, MTM&H – USAF Air Force Research Laboratory, USA
- CAPT. Charles Ciccone – USN Naval Aerospace Medical Institute, USA
- CDR. Gregory Cook – Office of the Command Surgeon, USJFCOM, USA
- Major Scott Farley – US Army UAS Proponency Office, USA
- Dr. Gary Gilbert, PhD – USATATRC, USA
- Mr. Gerald Jones – Office of the Command Surgeon, USJFCOM, USA
- CW3 Corey Lefebvre – TRADOC UAS Program Office, USA
- LTC. Li Kenyi – AFSOC, USA
- COL. Robert Mitchell – U.S. Army MEDEVAC Proponency Office, USA
- COL. Dana Renta – USAARL, USA
- COL. Glenn Rizzi – US Army UAS Proponency Office, USA
- MAJ. (RET) Jeff Warren – Directorate of Medical Evacuation Proponency, U.S. Army, USA
- LTC. Atzmon Yoav – R&D Section, Ministry of Defence, Israel

Our thanks are also extended to the industry representatives who have provided briefings and other information about the state of the art, without which this effort could not have been successful. These representatives include those from Aeronautics LTD, Aurora Flight Sciences, Cassidian Corporation, EADS North America, Israel Aerospace Industries, Piasecki Aircraft Corporation, Sikorsky USA, Urban Aeronautics, and Westland-Augusta Corporation.

## HFM-184 Membership List

### GERMANY

BG. (Ret) Erich Rödiger, M.D. (Chair)  
Berliner Strasse 52  
D-53819 Neunkirchen  
Tel: (++49) (0) 2247-4947

COL. (Ret.) Michael Howell  
Oak Ridge Partnership Office  
301 Sparkman Drive  
Huntsville, AL 35899  
Tel: (++1) 256-722-5576 x 23

### ISRAEL

LTC. Elon Glassberg, M.D., M.H.A.  
The Trauma & Combat Medicine Branch  
The Surgeon General's HQ  
IDF Medical Corps, Mil.  
P.O. Box 02149  
Tel: (++972) 3-737-9283

COL. Stephen Kenney  
30th Medical Command (United States Army)  
APO AE 09042  
Tel: (++49) 6221-17-2208

COL. Gil Hirschorn, M.D., M.H.A.  
Israel Defence Force Medical Service  
Yaara 56 Qiryat Tivoon 36520  
P.O. Box 4716  
Tel: (++972) 3-737-9120

COL. (Ret.) David Lam, M.D., M.P.H.  
US Army Telemedicine and Advanced  
Technology Research Center  
University of Maryland Medical School  
(RTG Secretary and Report Editor)  
PSC 79, Box 145  
APO AE 09714  
Tel: (++32)-(0)2-757-0621

### UNITED KINGDOM

WGCDR. Ian Mollan, MB, ChB, DAvMed,  
DOccMed, MRACs  
UK Royal Air Force  
18 Cedar Road, Carterton  
Oxfordshire, OX18 1HR  
Tel: (++44) (0)1993-841330

COL. Geoffrey Ling, M.D., PhD  
US Defense Advanced Research Projects Agency  
675 N Randolph Street  
Arlington, VA 22203  
Tel: (++1) 571-218-4674

### UNITED STATES

Dr. Khalid Barazanji, PhD  
US Army Aeromedical Research Laboratory  
6901 Andrews Avenue  
Ft. Rucker, AL 620577  
Tel: (++1) 334-255-6888

COL. (Ret.) James McGhee  
U.S. Army Aeromedical Activity  
Building 110  
Fort Rucker, AL 36362  
Tel: (++1) 334-255-0749

Mr. Michael Beebe, M.A., B.G.S.  
US Army Telemedicine and Advanced  
Technology Research Center  
504 Scott Street, Building 1054  
Ft. Detrick, MD 21702  
Tel: (++1) 301-471-3567

Mr. Martin Quattlebaum  
U.S. Army Aeromedical Activity  
Building 110  
Fort Rucker, AL 36362  
Tel: (++1) 334-255-0749

Mr. Pete Chambers, B.A.  
VP Marketing Assessment, Inc.  
22831 Silverbrook Center Drive, #145  
Sterling, VA 20166  
Tel: (++1) 703-673-9003

CW3 (Ret.) John Ramiccio, B.S.  
US Army Aeromedical Research Laboratory  
(USAARL)  
Attn: Flight Systems Branch  
Building 6901 Farrel Road  
Fort Rucker, AL 36362  
Tel: (++1) 334-255-6957

## **UNITED STATES (cont'd)**

COL. Hadley Reed, M.D., M.P.H.  
Chief, International Training Division  
USAF School of Aerospace Medicine/ETO  
2510 Fifth Street  
Wright-Patterson AFB, OH 45433-7913  
Tel: (++1) 937-938-3023

GPCAPT. Donald Ross MBA, MBChB, DCH,  
DAvMed, MRaES  
UK Royal Air Force  
2111 Silentrete Drive  
Vienna, VA 22182  
Tel: (++1) 703-678-1701

MAJ. Leonardo Tato, M.H.S.  
OUSD (P&R) Research Regulatory Oversight  
5113 Leesburg Pike, Skyline 4, Suite 901  
Falls Church, VA 22041  
Tel: (++1) 703-578-8577

LTC. Scott Walter  
US Special Operations Command, HQ  
AFSOC/SGR  
100 Bartley Street  
Hurlburt Field, Florida 32544  
Tel: (++1) 850-884-1935

# **Safe Ride Standards for Casualty Evacuation Using Unmanned Aerial Vehicles**

## **(STO-TR-HFM-184)**

### **Executive Summary**

The aim of this document is to investigate and make recommendations regarding the potential use of Unmanned Aerial Vehicles (UAVs)<sup>1</sup> for the transportation of casualties. Development of these recommendations has involved a review of all aspects of this type of vehicle, the legal and ethical considerations for such use, the operational and clinical considerations, and the development of possible scenarios in which such use could be beneficial to the casualty. This study has resulted in a set of recommendations for future research and development to support such potential usage, as well as some recommendations for doctrine development by various NATO bodies and clinical guidelines for such usage.

Aerial evacuation has become the “gold standard” for evacuation mechanisms. The flight parameters of these aircraft are controlled by on-board pilots, and thus are usually within the tolerance limits of casualties. However, there is not any internationally recognised set of tolerable physiological standards for casualties which can be used in development of flight profiles for Unmanned Aerial Vehicles (UAVs) – this is of special concern since some UAVs have the ability to potentially create physiological stresses far in excess of those produced by most current evacuation aircraft. Potential use of these vehicles for this purpose will likely be far-forward, and will involve the transport of freshly wounded, unstable, casualties, who may be more susceptible to physiological stresses than would be stabilised casualties. If UAVs are to be used in a casualty evacuation role, it is necessary to have an agreed set of physiological, flight, and materiel parameters which can be used by decision-makers to decide whether or not a casualty is suitable for evacuation by means of a UAV, or conversely, if a specific UAV is suitable for evacuation use.

The issue which this document addresses is both operationally and clinically relevant. The use of UAVs has shown great progress in recent years in multiple roles, and it appears evident that logistics-capable UAVs capable of carrying casualties will be present on the battlefield in the forces of several Nations within the short to medium-term<sup>2</sup>. Many doctrine developers are beginning to plan for the use of these aircraft for casualty extraction or evacuation on “back-haul”, after the UAVs have delivered their cargo. Initially sceptical about such potential usage, our RTG has come to believe that these aircraft will be used for casualty movement soon after their appearance on the battlefield, with or without doctrinal guidance. NATO and national Special Operations Forces have clearly indicated their interest in such use, when regular aerial evacuation means are either not available or are operationally undesirable, as have several Nations’ conventional military forces. This potential use of UAVs as a solution to the need for evacuation demands the creation of safe ride standards for such use. We have developed a set of guidelines to make this modality safe to use in certain circumstances.

---

<sup>1</sup> Definitions for unpiloted aerial vehicles are in a state of flux. The classic term “UAV” is being replaced in some fora by “Unpiloted Aerial System (UAS)”, and some Nations and services are starting to use the term “Remotely Piloted Vehicle (RPA)”. For this document, we have chosen to generally use the term “UAV” when referring specifically to the vehicle, and “UAS” when an entire system is meant.

<sup>2</sup> In fact, the first Logistics-capable UAVs to be fielded are currently flying in Afghanistan. Though these particular aircraft do not have the capability to internally carry a reclining casualty, it appears evident that future cargo-carrying UAVs will have such a capability.

This document reviews the current state of UAV development, NATO doctrine and policy addressing this issue, legal and regulatory issues, as well as the clinical aspects of such transport, and it presents a set of recommendations for NATO and the RTO which the RTG believes will ensure that when such use becomes reality, it will be without detriment to the casualties being moved. The RTG has recommended changes and additions to NATO doctrine in this regard, as well as proposing continued research which is necessary to develop truly evidence-based safety-of-flight recommendations. We have identified improvements in medical equipment which are necessary before any detailed consideration can be given to future use of UAVs for true medical evacuation.

It is the conclusion of the RTG that the potential use of UAVs for casualty evacuation (CASEVAC) is ethically, legally, clinically, and operationally permissible, so long as the relative risk<sup>3</sup> for the casualty is not increased through the use of the UAV. The use of this type of aircraft for Medical Evacuation (MEDEVAC) is neither technologically possible nor acceptable at this time (primarily due to lack of capability of in-flight medical equipment), though we believe that such use will be possible in the medium to distant term.

---

<sup>3</sup> "Relative risk" is defined as "The potential loss that can result from one action measured against the potential loss that might result from a different action". In other words, it is the comparison of the risk of being moved in a UAV versus the risks incurred by not moving a casualty by this means.



# Normes de transport sans danger pour l'évacuation des blessés par véhicules aériens sans pilote

(STO-TR-HFM-184)

## Synthèse

Le présent document a pour but d'examiner et de produire des recommandations concernant l'utilisation potentielle de véhicules aériens sans pilote (UAV)<sup>4</sup> pour le transport de blessés. Le développement de ces recommandations a impliqué une étude de tous les aspects de ce type de véhicule, des considérations juridiques et éthiques d'une telle utilisation, des considérations cliniques et opérationnelles, ainsi que le développement des scénarios potentiels dans lesquels une telle utilisation serait un avantage pour les blessés. Ladite étude a donné lieu à un ensemble de recommandations destinées à de futures recherches et développements pour appuyer une telle utilisation potentielle. En ont également résulté des recommandations pour le développement de doctrines par divers organismes de l'OTAN et des directives médicales pour cette utilisation.

L'évacuation aérienne est devenue la « référence » en matière d'évacuation. Les paramètres de vol de ces aéronefs sont contrôlés par des pilotes embarqués et entrent par conséquent dans les limites de tolérance des blessés. Il n'existe toutefois aucun ensemble de normes physiologiques tolérables concernant les blessés qui soit reconnu à l'échelle internationale et puisse être utilisé dans le développement de profils de vol de véhicule aérien sans pilote (UAV). Cela est particulièrement à prendre en considération puisque certains UAV peuvent engendrer un stress physiologique bien supérieur à celui provoqué par la plupart des avions d'évacuation actuels. L'horizon d'utilisation potentielle de ces véhicules dans ce but sera probablement très lointain et impliquera le transport de blessés récents et instables, plus sensibles au stress physiologique que ne le seraient des blessés stables. Si les UAV doivent être utilisés dans un rôle d'évacuation des blessés, il est nécessaire de s'accorder sur un ensemble de paramètres physiologiques, de vol et de matériel qui sera utilisé par les décideurs afin d'établir si un blessé est apte à être évacué par le biais d'un UAV ou à l'inverse, si un UAV particulier est approprié à l'évacuation.

La question traitée dans le présent document est pertinente du point de vue opérationnel et clinique. Ces dernières années, de grands progrès ont été faits dans l'utilisation des UAV dans de multiples rôles et il semble évident que les UAV à capacité logistique capables de transporter des blessés seront présents sur le champ de bataille auprès des forces de plusieurs nations à court ou moyen terme<sup>5</sup>. De nombreux responsables de la doctrine commencent à prévoir l'utilisation de ces aéronefs pour l'extraction ou l'évacuation des blessés « au retour », une fois que les UAV ont déposé leur cargaison. Quoique sceptique de prime abord au sujet d'une telle utilisation potentielle, notre RTG pense à présent que ces aéronefs seront utilisés pour le déplacement des blessés peu après leur apparition sur le champ de bataille, avec ou sans orientation basée sur une doctrine. L'OTAN et les forces d'opérations spéciales – ainsi que les forces militaires conventionnelles de nombreux pays – ont clairement manifesté leur intérêt pour une telle

<sup>4</sup> La définition des véhicules aériens sans pilote est actuellement fluctuante. Le terme classique « UAV » est en passe d'être remplacé dans certains forums par « système aérien sans pilote » (UAS, *Unpiloted Aerial System*) et certains pays et services commencent à utiliser le terme « véhicule piloté à distance » (RPA, *Remotely Piloted Vehicle*). Pour le présent document, nous avons choisi d'utiliser de manière générique le terme « UAV » lorsqu'il est spécifiquement fait référence au véhicule et « UAS » lorsqu'il s'agit de tout un système.

<sup>5</sup> Les premiers UAV à capacité logistique à mettre en service sont actuellement utilisés en Afghanistan. Bien que ces aéronefs en particulier n'aient pas la capacité interne de transporter un blessé en position allongée, il semble évident que les futurs UAV de fret auront une telle capacité.

utilisation lorsqu'un moyen d'évacuation aérienne classique n'est pas disponible ou souhaitable au niveau opérationnel. Cette utilisation potentielle d'UAV comme solution d'évacuation requiert la création de normes de transport sans danger à cette fin. Nous avons développé un ensemble de lignes directrices afin de rendre l'emploi de cette modalité sans danger dans certaines circonstances.

Le présent document examine l'état actuel du développement des UAV, de la doctrine et de la politique de l'OTAN qui traitent de cette question, les questions de lois et réglementations, ainsi que les aspects cliniques d'un tel transport. Il y est présenté un ensemble de recommandations destinées à l'OTAN et la RTO ; le RTG est convaincu que celles-ci garantiront un transport tout à l'avantage des blessés lorsqu'une telle utilisation deviendra réalité. Le RTG a recommandé des modifications et ajouts à la doctrine de l'OTAN à cet égard et a également proposé de maintenir la recherche, ce qui est nécessaire pour véritablement développer des recommandations de sécurité en vol basées sur des éléments tangibles. Nous avons identifié des améliorations à effectuer sur le matériel médical qui s'avèrent nécessaires avant de pouvoir considérer en détail l'utilisation future des UAV pour une réelle évacuation médicale.

Le RTG conclut que l'utilisation potentielle des UAV pour l'évacuation des blessés (CASEVAC) est admissible sur les plans éthique, juridique, clinique et opérationnel, tant que le risque relatif<sup>6</sup> pour les blessés ne se trouve pas accru par l'utilisation de l'UAV. L'utilisation de ce type d'aéronef pour l'évacuation sanitaire (EVASAN) n'est à l'heure actuelle ni technologiquement possible, ni acceptable (principalement en raison du manque de capacité au niveau du matériel médical en vol), bien que nous soyons convaincus qu'une telle utilisation sera possible à moyen ou long terme.

---

<sup>6</sup> Le « risque relatif » est défini comme « la perte potentielle pouvant résulter d'une action par rapport à la perte potentielle pouvant résulter d'une action différente ». En d'autres termes, il s'agit d'une comparaison entre le risque d'un déplacement en UAV et les risques encourus si le blessé n'est pas déplacé par ce moyen.

## **Chapter 1 – INTRODUCTION AND BACKGROUND**

### **1.1 INTRODUCTION**

Not all aircraft are suitable for use in casualty transport. Even assuming adequate internal carriage space for casualties, some aircraft are, due to their normal flight profiles, simply not a good choice for this mission. For example, most of us would agree that putting a casualty in an aircraft like the Tornado in its normal operational envelope would not be in the best interests of very many casualties. Generally speaking, aircraft used to carry casualties in both military and civilian settings are representative of common aircraft in use for multiple purposes, but are at the lower end of the performance envelope. The flight parameters of aircraft currently used for aerial evacuation are controlled by on-board pilots, and thus flight profiles are usually maintained within the tolerance limits of casualties with varying degrees of disability/injury. However, there does not appear to be any internationally recognised set of tolerable physiological standards for casualties which can be used in development of flight profiles for Unmanned Aerial Vehicles (UAVs) – this is of special concern since some UAVs (like fighter aircraft) have the ability to potentially create physiological stresses (e.g. acceleration forces) which would be detrimental to the condition of a wounded casualty. If UAVs are to be used in a casualty evacuation role, it is necessary to have an agreed set of flight and physiological parameters which can be used by decision-makers to decide whether or not a casualty is suitable for evacuation by means of a UAV, or conversely, if a specific UAV is suitable for evacuation use. This is necessary no matter whether we are discussing UAVs in the sense of fully autonomous aircraft, piloted by on-board artificial intelligences unassisted by human pilots, or in the sense of a remotely piloted aircraft with a human pilot physically located at some distance. Potential use of these vehicles for this purpose will likely be far-forward, and will involve the transport of freshly wounded, unstable, casualties, who may be more susceptible to physiological stresses than would be stabilised patients.

### **1.2 THE UTILITY OF AEROMEDICAL EVACUATION**

Since the first use of routinely carried out Aeromedical Evacuation, nearly every newly developed aircraft type has been tried as a casualty transport platform (see Annex B). In current military operations, the impact of helicopter evacuation times is a significant factor when it comes to casualty survival, which is at the highest level ever seen in military history. This fact has contributed to bringing the survival rates of U.S. Forces' casualties in Afghanistan and Iraq up to 89.9% compared to 69.7% in World War II<sup>1</sup>. It appears that the next aircraft type to be used in this role may well be the UAV.

### **1.3 THE RISE OF UAVs**

The use of Unmanned Aerial Vehicles (UAVs) in many roles is one of the fastest-growing of all fields in military aviation. Though the use of several varieties of UAVs for operational military purposes has most recently been brought to public attention as the result of their use in Afghanistan and Pakistan, there is much more development going on than most people realize. About 60 different models from 16 different countries were shown at the 2009 Paris Air Show<sup>2</sup> and many more are known to members of this RTG. It has recently been stated (correctly, we believe) that:

---

<sup>1</sup> Defence Technology International, October 2010.

<sup>2</sup> UVS News Flash, 30 June 2009.

*“Today, Unmanned Aircraft Systems (UAS) are at a comparable stage of infancy to manned aircraft of the 1920s. Technological possibility, operational necessity, and popular support for unmanned systems have converged in much the same way that they did for aircraft development early last century.”<sup>3</sup>*

UAVs have in recent years become ever more versatile and essential assets on the battlefield. Current rapid development and fielding of UAVs provide the opportunity to evaluate the potential of this new type of aircraft for the transportation of casualties. Problems with user trust in aircraft autonomy will potentially become more acute as technical innovation allows for more rapid and independent UAV decision-making. A UK MOD Report released in March 2011<sup>4</sup> predicted that artificial intelligence in UAVs (total independence from human control) could be anywhere from 5 – 15 years away. If such development occurs, that potential could raise both ethical and legal questions, and might create psychological barriers for moving casualties in UAVs, but any UAVs suitable for this use in the near-term will most likely be remotely piloted, rather than relying on artificial intelligence for their entire flights. Therefore, most of the work of this RTG has concentrated on the evaluation of Remotely Piloted Aircraft (RPA) for this task in the near-term.

### 1.3.1 The Development of Cargo/Logistics UAVs

Although most current military utilization of UAVs is for ISTAR (Intelligence, Surveillance, Target Acquisition and Reconnaissance) or armed attack, there is an increasing world-wide interest in the concept of cargo-capable or logistics UAVs. It has more recently been realized that many more missions are potentially suitable for this category of aircraft, especially as unpiloted or remotely piloted RW and Ducted Fan (DF) aircraft are being developed. Unmanned systems may also enable sustainment and force support operations through the automation of critical missions, including: assured mobility, transportation, distribution, maintenance, explosive ordnance disposal, CBRN support, communications, and health services. For purposes of this report, the RTG has been especially struck by the great degree of interest in and concurrent development of RW/DF UAVs for battlefield sustainment (logistics), as aircraft designed for this mission seem to be the most likely to have casualty evacuation capability.

Several militaries, along with NATO, have written the concept of cargo-capable UAVs into their concept plans for future development<sup>5,6</sup> and several forces have raised the issue of the potential use of these aircraft for casualty evacuation. As only one example, the U.S. Special Operations Forces Long Endurance Demonstrator (SLED) Advanced Concept Technology Demonstration (ACTD) is in an Extended Use Evaluation. The SLED ACTD uses the A-160 Hummingbird unmanned aerial vehicle to demonstrate a Vertical Take-Off and Landing (VTOL) aircraft capable of flying long range that can employ a wide variety of adaptable Special Operation Forces payloads at various altitudes. One of these study portions will be the use of the payload pod to conduct emergency recovery of personnel. If successful, this study has obvious implications for potential use in CASEVAC missions.

This is not as far-fetched as it may seem, for there is historical precedent. During the War in Vietnam, there is anecdotally at least one and possibly several cases in which the U.S. Navy’s DASH-50 remotely piloted aerial vehicle, though designed for anti-submarine warfare, was used to extract an individual from behind enemy

---

<sup>3</sup> General Dynamics Information Technology. “Future Modular Force Resupply Mission for Unmanned Aircraft Systems (UAS)”.

<sup>4</sup> United Kingdom Ministry of Defence. “Joint Doctrine Note 2/11 – The UK Approach to Unmanned Aircraft Systems”.

<sup>5</sup> NATO Joint Air Power Competence Center. “Strategic Concept of Employment for Unmanned Aircraft Systems in NATO”.

<sup>6</sup> United States Army UAS Center of Excellence, “Eyes of the Army – U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035”.

lines. The U.S. Navy, during this same period, formally developed a modification of the DASH-50 for the rescue of downed pilots, some of whom would have been expected to be injured (Project Midget)<sup>7</sup>.



Figure 1-1: U.S. Navy / Gyrodyne Corporation Slide on Project “Midget”, Undated, but During the Vietnam War.

### 1.4 SCOPE OF THE STUDY

For the scope of this document, an Unmanned Aerial Vehicle (UAV) consists of a powered physical system, with no human operator aboard the principal platform, which acts in the aerial environment to accomplish assigned tasks. Operational control may conceivably be maintained by a remote pilot operating at a distance, or by a totally autonomous vehicle which is pre-programmed for the mission, and which thereafter operates without “human pilot” control. An Unmanned Aerial System (UAS) includes both the UAV itself and all associated supporting components such as Operator Control Units (OCU) and communications systems.

Examples of unmanned systems may include Unmanned Aerial Systems (UAS), Unmanned Ground Systems (UGS), and Unmanned Maritime Systems (UMS). For purposes of this report, only the aerial sub-category

<sup>7</sup> Hirschberg, M.J., “To Boldly go where no unmanned aircraft has gone before: A half-century of DARPA’s contributions to unmanned aircraft”.



## INTRODUCTION AND BACKGROUND

---

will be examined, though much of this analysis would directly apply to the use of ground or maritime systems for the same purpose. An unmanned system, operated remotely or with some degree of autonomy, can be designed to carry human passengers, and still remain categorized as an unmanned system, even though a more appropriate term might be “unpiloted”. Although the term “UAS” is rapidly replacing “UAV” in common use (since the aerial vehicle itself will not function in the absence of the other parts of the system), in this report we will use the term UAV as referring to the aircraft itself – the other components of the UAS as a system will have significantly less direct impact on the safety of the casualty, until and unless we begin installation and distant control of medical devices or telemedicine on these platforms.

### 1.5 TRAUMA CARE AND THE NEED FOR EVACUATION

The first 60 minutes after a traumatic injury has been referred to in the past as the “golden hour”. Though this concept has been modified based on recent combat experience<sup>8</sup>, it is clear that the chances of survival for critically injured trauma patients depend on rapid access to ATLS stabilisation and surgical care. Delivering an injured casualty to an appropriate level of care within the prescribed time constraints is the goal of Medical Evacuation (MEDEVAC) or Casualty Evacuation (CASEVAC). Current NATO doctrine has modified this requirement somewhat, with the so-called 10-1-2 concept, which mandates that:

- “Bleeding and airway control for the most severely injured casualties must be achieved within 10 minutes of wounding;
- Medical evacuation assets (surface or aviation) should reach the seriously injured casualty with advanced skilled medical aid within 1 hour of wounding at the latest; and
- Casualties requiring surgery must be within a facility equipped to provide this within 2 hours of wounding at the latest.”<sup>9</sup>

Current operations by the International Security Assistance Force – Afghanistan (ISAF) have demonstrated that this goal cannot always be met, often due to operational requirements or simple unavailability of dedicated medical evacuation aircraft. The rise in the availability of man-portable anti-aircraft missiles, as well as the extended distances involved in operations such as those being carried out by ISAF, have placed an ever-increasing burden on the forward air ambulances available. It is not always proving possible to respond with equipped and crewed air ambulances in a timely manner, especially in light of the new NATO 10-1-2 policy.<sup>10</sup> Further, isolated operational units (e.g. SOF) may suffer casualties but for operational reasons may not be able to accept evacuation by large and noisy dedicated air ambulances, or the risk to manned assets needed to support them may be unacceptable.

Present evacuation trends indicate that both air and ground ambulances will continue to serve in the battle areas of the future, but the increased depth, width, and complexity of the operational areas indicates a recurring need for both lateral and rearward movement. In this context, smaller and quieter aircraft, whether manned or unmanned, may prove safer and more capable of responding in a timely manner. Therefore, it appears evident that all potential means for achieving these goals must be considered, including possible use of UAVs (see Chapter 4 below for a potentially viable operational concept).

---

<sup>8</sup> Remick, K.N. et al., “Transforming US Army Trauma Care: An Evidence-Based Review of the Trauma Literature”.

<sup>9</sup> AJP-4.10(B) (Draft 1.1).

<sup>10</sup> AJP-4.10(B) (Draft 1.1), para 1024.

## **1.6 UAVs AND CASEVAC**

It has been recommended by many authors that the use of UAVs for CASEVAC may offer a viable alternative method for casualty extraction or evacuation. If UAVs are present on the battlefield for logistics support, they may provide a capability for CASEVAC which could serve in specific instances as a supplement to dedicated RW or Tilt-Rotor (TR) air ambulances. One additional factor which must be considered in the risk/benefits analysis is that aerial CASEVAC or MEDEVAC, executed with manned assets, places additional lives at risk, beyond that of the casualty. Recent losses in combat of manned MEDEVAC aircraft clearly demonstrate this risk, as do the records of air ambulance losses experienced by the United States in Vietnam. It is conceivable that the use of UAVs for CASEVAC under certain circumstances might effectively reduce the exposure of aircrews to enemy fire, while carrying out a casualty extraction to a safer location where the casualty can be transferred to a dedicated air ambulance with more medical capability than can be provided on the UAV. Although a UAV might not be equipped to provide care en route, time would not be lost in either configuring the aircraft for medical personnel and supplies or in arranging escort gunships, and thus the time lost before the casualty can reach advanced medical care (e.g. that provided by a “real” air ambulance and its crew or found at an advanced medical facility) could be reduced.

The author of one of the first studies to look at the potential use of UAVs for casualty evacuation discussed his concept as follows:

*“The current battlefield is changing rapidly. Combat operations against irregular forces are set in a dispersed, non-linear battlefield. Vast distances between small units such as the infantry squad, and the distances from these small elements to their supporting organizations, pose unique challenges. Casualty evacuation is an evolving challenge. The goal of casualty evacuation is to transport an injured Marine from the point of injury to a medical care facility. Increased dispersion results in longer distances from the point of injury to medical care facilities with a corresponding increase in the delay between the time of injury and lifesaving surgical care. The non-linear aspects of this battlefield increase the threat to aircraft crews and platforms conducting casualty evacuation. Unmanned aerial systems offer an alternative means of air casualty evacuation. This alternative may provide time-critical response while reducing threat to aircraft crews.”<sup>11</sup>*

Although this author originally referred only to United States Marines, the potential applicability of this concept to all NATO forces seems evident.

## **1.7 BACKGROUND TO THE CREATION AND WORK OF THIS RTG**

Realising that the safety and effectiveness of UAVs for this role has not yet been successfully demonstrated in spite of many ongoing studies and experiments, and taking into account the fact that some UAVs now in development have possible flight parameters which are on their face not suitable for healthy human beings, much less casualties, in 2008 it was recommended to the Human Factors and Medicine Panel of the NATO Research and Technology Organisation (RTO) that an RTG be established to look into this issue. As a result, in August 2009 the RTO established a Research Technical Group (RTG) to study this issue and to evaluate the state of the art with regard to UAV development, and to create a set of safe ride standards for casualty evacuation using unmanned aerial vehicles. This activity has attempted to develop an evidence-based reference resource which can be used by UAV developers and line commanders who may have to make the decision to use one of these vehicles for this purpose. A selected international group of aeromedical and

---

<sup>11</sup> Featherstone, R.L., “Determination of Critical Factors in Unmanned Casualty Evacuation in the Distributed Environment”.

## INTRODUCTION AND BACKGROUND

---

aeronautical engineering researchers, clinicians, pilots, doctrine developers and medical operators jointly investigated this potential addition to NATO's armamentarium. The group has considered the flight characteristics of potentially suitable UAVs as well as aeromedical factors which must be met to ensure that any such evacuation is not detrimental to the casualty. An agreed prerequisite was that UAVs for this purpose must meet the same safety standards as currently used in man-rated rotary wing aircraft (crashworthiness, redundant flight systems, etc.).

It was highlighted during the work of the RTG that what must be discussed is relative risk, not absolute risk. Evacuation cannot be accomplished without risk, no matter what transportation mechanism is used. The use of current helicopters and tilt-rotor aircraft entails a certain level of risk, even without the additional risks of being wounded. If the use of UAVs for evacuation is to be successful, it is imperative to develop a situation in which the use of UAVs for the opportune lift of casualties is no more dangerous than is an evacuation using a currently available helicopter, from the casualty's viewpoint. Mitigated risk is a key term, which should be considered in all such decisions. The real question which will need to be answered in each case is, "Is it more dangerous to move the casualty in an available UAV or to leave him where he is until a non-UAV transport can be arranged?" It has been our goal to assist the potential user in making this decision, and to choose which UAV to use for this purpose, in the event that more than one type is available.

To fully evaluate this potential new modality, this RTG has carefully investigated the current state of the art of UAV design, as well as the licensing and regulatory restrictions which may affect the legality of placing live humans on this type of aircraft, and has attempted to develop an evidence-based reference resource which can be used by line commanders to ensure that the use of such aircraft for this purpose will not be detrimental to the health and well-being of the casualty potentially being moved. Unfortunately, although most types of aircraft have been successfully used for the movement of casualties for many years, there is a dearth of evidence-based data which actually shows the safety of current aeromedical evacuation practices, and which can be used for comparison. The fact that most casualties survive their aerial journeys, and that most practitioners believe that this means of transport is the best possible transportation means in a combat environment, does not prove that such transport is not in any way detrimental. For example, we can demonstrate that casualties with head injuries can survive transport by helicopter, but it has never been convincingly demonstrated that such individuals do not suffer additional damage from the stresses experienced in flight. We have identified and recommended the accomplishment of future medical research necessary to definitively prove this, though actually carrying out this research is beyond the capabilities of this RTG.

The RTG has also investigated the psycho-physiological stressors which may affect casualties in flight, including vibration, noise, acceleration, temperature, motion sickness and cabin air as well as other occupational hazards. The group focused also on the possibility of medical assistance in flight, in-flight monitoring, and telemedicine. The extent to which closed loop medical monitoring and specialised treatment will be usable in the future is still being investigated and is the subject of much research and development, but appears feasible in the longer term.

## 1.8 TYPES OF EVACUATION

There is a doctrinal distinction which we have had to consider – that between Medical Evacuation and Casualty Evacuation. "Medical Evacuation" (MEDEVAC) is defined as "The medically supervised process of moving any person who is wounded, injured or ill to and/or between medical treatment facilities as an integral part of the treatment continuum."<sup>12</sup> Thus, this type of patient movement is under medical control,

---

<sup>12</sup> AMEDP-13 (A).



and mandates the provision of necessary medical care en route, along with the use of appropriate medical attendants to provide care in flight. On the other hand, “Casualty Evacuation” (CASEVAC) is defined as “The non-medicalised evacuation of patients without qualified medical escort.”<sup>13</sup> The latter is not under medical control, but is controlled by the line, and makes use of non-medical vehicles of opportunity when for whatever reason adequate support cannot be provided by dedicated manned evacuation platforms. This distinction is significant – a logistics UAV can theoretically be used for patient evacuation, without accompanying medical personnel or treatment in flight, and without a requirement for specialised medical equipment, as can other non-medical aircraft and ground vehicles – such use may be less than optimal as compared to the use of fully-equipped air ambulances, but is frequently accomplished during today’s operations. Understanding of this distinction is critical, since the technological readiness of both the UAVs and supporting medical materiel to accomplish these two missions is widely different – Any given aircraft may or may not be suitable for both missions, and it appears that, while theoretically possible, the use of UAVs to provide true MEDEVAC is significantly further in the future than is the use of UAVs for CASEVAC. Use of a UAV for true medical evacuation would require successful development of increased and more reliable on-board autonomous medical capabilities, and would probably require the vehicle to be significantly larger than is currently envisioned for many logistics UAVs – in essence, whilst the use of UAVs for dedicated medical evacuation is conceivably possible, this was not the primary focus of our group’s work. It has been neither our goal nor our desire to recommend the replacement of current aeromedically-configured aircraft by UAVs, but simply to define a set of criteria which will allow non-medical UAVs to be occasionally used for CASEVAC as an additional mission, to supplement dedicated medical evacuation platforms when desired or necessary due to operational constraints. It is clear that not all UAVs will be able to be successfully used for CASEVAC missions, but it is also clear that with adequate knowledge of design criteria and careful selection of the aircraft to be used, there are no inherent operational, medical, or aeronautical reasons that some UAVs will not be able to function successfully in this role. Some writers opine that there are ethical reasons that UAVs cannot be used for this purpose<sup>14</sup>, but our group is of the opinion that such arguments are fallacious, being based primarily on a fundamental misunderstanding of the differing concepts of MEDEVAC and CASEVAC. A full discussion of the ethical issues is found in Chapter 8. In the future, we believe it is conceivable that true medical evacuation could make use of UAVs – however, that may require significant advances in medical technology (closed loop monitoring/treatment systems and improved telemedicine capabilities). Such use has not been the focus of our discussions, and we do not believe that such use is going to be realistic in the short term.

## **1.9 POSSIBLE OPERATIONAL USE OF UAVs FOR EVACUATION**

Notional operational scenarios (CONOPS) using UAVs for casualty extraction have been developed which could support both clinical and operational requirements as part of an overall medical support concept. In this document several potential CONOPS proposals are added as food for thought (see Chapter 4). In some circumstances, it appears that Unmanned Aerial Vehicles (UAVs) may be able to offer an alternative means of providing air CASEVAC. This alternative may provide a time-critical response, enabling the users to meet the NATO time to treatment mandates, while reducing the threat to aircraft crews. Blanket rejection of this concept without excellent rationale should therefore be avoided.

---

<sup>13</sup> AMEDP-13 (A).

<sup>14</sup> US Army AMEDD Center and School – “Memorandum: Directorate of Combat and Doctrine Development’s Position on Use of Unmanned Aerial Vehicles (UAV) for Patient Movement”.

## **1.10 OBJECTIVES**

It is important to note that this group does not advocate total replacement by UAVs of manned AE vehicles, which will still remain the “gold standard” for casualty care for the foreseeable future, but simply has taken into account the potential use of UAVs in supplementing other evacuation capabilities. In some military scenarios (e.g. asymmetric and urban warfare), the use of UAVs could conceivably be lifesaving and might shorten the interval for medical response (e.g. if manned air ambulances cannot be used for any reason, while a suitable UAV might be available). This could positively influence both mission accomplishment and casualty survival. Our report demonstrates the conceptual benefits and acceptability of UAVs as an auxiliary casualty evacuation platform. It provides guidelines for aircraft choice and clinical criteria which can ensure that this new modality will not impair the casualty’s condition but which will enhance the medical outcome.

This activity was tasked to attempt to develop an evidence-based reference resource which can be used by UAV developers to ensure that either remote pilots or the Artificial Intelligence programs used to control<sup>15</sup> UAVs will be able to support the use of these airframes in the casualty evacuation role. Our ultimate goal has been to develop guidelines by which medical and line personnel can determine whether casualty evacuation by UAV should be supported, in the best interests of the casualty, given current limitations of the clinical knowledge base. Absolute G tolerances of casualties with various injuries have been investigated, as were the rate of G-onset and other physiological and flight parameters. The majority of this work has been done through literature search and coordination with regulatory/scientific agencies. Unfortunately, we have discovered that there is a dearth of such evidence-based criteria to be found in the literature.

Topics covered during our discussions have included:

- Status of Development and Flight Characteristics of UAVs (current, developmental and projected);
- Control Mechanisms for UAVs, including Remotely Piloted Vehicles (RPV) and controlled by on-board programming (Artificial Intelligence);
- The potential use of UAVs for casualty evacuation – operational and logistics considerations;
- Human Systems Integration (HSI) for UAVs used for casualty evacuation;
- G-tolerance and rate-of-onset tolerance of casualties in various axes and with differing medical conditions;
- Psycho-Physiological Stresses potentially encountered;
- In-fight medical support capabilities; and
- Possible scenarios in which UAVs could serve in casualty evacuation.

In describing the characteristics of UAVs and how they may affect UAV utilization as an evacuation platform, we have identified needed additional research in order to make such capability an acceptable modality and to become a viable addition to NATO’s evacuation chain (see Chapter 7).

## **1.11 HUMAN SYSTEMS INTEGRATION**

The issue of Human Systems Integration has played a significant role in our discussions. The phrase “Human Systems Integration” captures the basic overarching concept of integrating the human into the engineering of

---

<sup>15</sup> Under “control”, we include more than piloting – we also have considered environmental controls, C2, etc.

the system.<sup>16</sup> Since we were not looking at any specific system, it was not the mission of this RTG to conduct a formal comprehensive Human Systems Integration analysis of this concept (and this document is not the place to put a full HSI evaluation). However, in developing this report and addressing the various issues, we found that we have in effect considered the various elements of HSI regarding this particular concept. The results were essentially a *de facto* HSI analysis, something that has not been done before to examine the use of UAV for the transport of personnel, much less of casualties.

The official U.S. Air Force definition of HSI states that:

*“HSI is the integrated and comprehensive analysis, design and assessment of requirements, concepts and resources for system manpower, personnel, training, environment, safety, occupational health, habitability, survivability, and human factors engineering, with the aim to reduce total ownership cost, while optimizing total mission performance.”<sup>17</sup>*

The goals of HSI are reflected in condensed form within U.S. DoD policy for the Defense Acquisition System<sup>18</sup>:

- Optimize total system performance.
- Minimize total ownership costs.
- Ensure that the system is built to accommodate the characteristics of the user population that will operate, maintain, and support the system.

The application of this methodology has validated the process used by RTG-184 in developing this paper. Some minor additional observations were made with this HSI method. However, the primary key findings on the subject of UAVs and safety issues associated with using them for transporting casualties has been matched by what the informal HSI process developed independently. Realizing that this effort is not complete, we still feel it is valuable, and may facilitate future work in this regard when a formal HSI on logistics UAVs is done. Our preliminary HSI analysis, restricted to those topics directly relevant to the use of UAVs in this context is found at Annex C.

## **1.12 DISCLAIMER**

In conclusion, it has to be noted that this report represents the informed opinion of the authors, and not necessarily those of industry and/or national and international military organizations.

## **1.13 THANKS**

As Chairman it is my pleasure and privilege to express my deep gratitude and appreciation to all members of the group for their dedication and their most professional contributions – Dr. Erich Rödiger, M.D., Chairman.

---

<sup>16</sup> Human Systems Engineering Branch of the Electronic Systems Lab of the Georgia Tech Research Institute; [http://hsimed.gtri.gatech.edu/hsi\\_info/hsi\\_intro\\_what.php](http://hsimed.gtri.gatech.edu/hsi_info/hsi_intro_what.php).

<sup>17</sup> AFI 10-601, Attachment 1.

<sup>18</sup> DoDI 5000.02, “Operation of the Defense Acquisition System”.



## Chapter 2 – UNMANNED AIRCRAFT SYSTEMS AND ENABLING TECHNOLOGIES

*“The unmanned vehicle today is a technology akin to the importance of radars and computers in 1935.” (Dr. Edward Teller, from a 1981 press conference).*

### 2.1 INTRODUCTION

The development of UAS has been ongoing since World War I, but it has only begun to achieve full functionality and capability in recent years. Although most UAS development has concentrated on ISTAR and strike capabilities, the use of these aircraft for cargo delivery and potential casualty transport seems to be a real possibility in the near future.

This chapter provides a brief overview of the current “*state-of-the-industry*” regarding Vertical Take-Off and Landing (VTOL) Unmanned Aircraft Vehicles (UAV) which are potentially capable of performing casualty transport missions in a tactical environment. The focus is on VTOL aircraft due to the tactical nature of the missions – urgent medical item resupply, short range casualty extraction (i.e. “over-the-hill”), Casualty Evacuation (CASEVAC), Tactical Evacuation (TACEVAC)<sup>1</sup>, Combat Search And Rescue (CSAR), and possibly eventual Medical Evacuation (MEDEVAC). The chapter also discusses proposed future VTOL UAVs and the enabling technologies which must be able to support these missions, and offers thoughts, conclusions and recommendations concerning these technologies.<sup>2</sup>

*“...would a means to fly in and extract isolated personnel without putting additional personnel in harm’s way be of value? The answer to that question is an obvious yes!” (CWO4 Michael Durrant, USA (Ret), Pilot SUPER SIX FOUR, 160<sup>th</sup> SOAR, Battle of Mogadishu, OPERATION GOTHIC SERPENT)*

### 2.2 POTENTIAL ADVANTAGES OF UAS

There are potential advantages of employing VTOL UAS for medical missions. The intent of those who espouse this new use for UAS is not to replace manned helicopters with UAVs, nor to replace pilots with computers. The intent is to add additional capability to that of the manned helicopter community by providing the ability to execute missions<sup>3</sup> when the:

- Weather is below safe flight minimums for manned flight;
- En route or terminal environment (landing zone) is contaminated by an industrial spill or by a CBRN event;
- En route or terminal environment is “Hot” (heavy threat); and

---

<sup>1</sup> This is a non-NATO and non-standard term which is used by some organisations (e.g. U.S. Marine Corps) to mean forward casualty evacuation with or without medical care en route, on non-dedicated aircraft. It is not the same as the NATO concept of Tactical or Theatre Aeromedical Evacuation.

<sup>2</sup> The UAS listed in this document are only examples – this list is not meant to be exhaustive or complete, but is representative. The inclusion of a system herein is not to be interpreted as providing any endorsement or support for a specific aircraft or system.

<sup>3</sup> A model would be the Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) community’s development and deployment of the Global Hawk UAS. Global Hawk has not replaced manned ISTAR platforms, but is a force multiplier, adding additional capability.

- Pilots or manned airframes are not available due to the number of sorties required, crew rest for safety, or other mission requirements.

Since the beginning of warfare military leaders have demanded additional and improved capabilities – “Technology Pull”, to give them an advantage over their opponents. The 21<sup>st</sup> Century is no different. Commanders want overmatching firepower at all echelons from the division down to the fire team. Commanders also want to reduce risk to their personnel and decrease the time and risk it currently takes to extract and evacuate casualties to definitive medical care. VTOL UAS offer commanders just that – less risk to flight crew, and potentially (sometimes definitely) faster response times for medical resupply or casualty rescue. However, the employment of VTOL UAS for medical missions will have to be operationally viable, not just feasible. A key element will be to emphasize UAS strengths to offset human (flight crew) weaknesses and vice versa. This issue of varying strengths and weaknesses is another reason that a UAS won’t totally replace pilots in this role for many years.

*“In 1903 the possibility of using combustion-driven vehicles to transport casualties from the battlefield was first raised. The idea was met with cynicism. One critic was heard to say, “nothing has been found to equal the force of the horse for economy and safety. Patients, being probably in a nervous condition, will be alarmed at the idea of being taken off in a motor car.” (Unknown source, but clearly indicative of the opinions of the era)*

Unmanned aircraft systems – semi-autonomous like the Global Hawk, Fire Scout, or KMAX, not tele-operated like the Predator class – bring computer-driven levels of accuracy, precision and repeatability humans cannot approach; and they don’t get scared. However, current UAS do not deal with ambiguity very well. Conversely humans, while they may not fly as accurately or as precisely as a semi-autonomous UAS, deal with ambiguity and uncertainty very well. Technologists, UAS system developers, military planners, and military commanders must keep this in mind, and must use the respective strengths of manned aircraft and UAS, while compensating for their respective weaknesses. This is why the common adage “use unmanned systems for the Dull, Dirty or Dangerous missions” forms the basis for much UAS concept development.

The developmental progress expected of UAS in the future has been well described, and in fact the development and testing of these systems have clearly been following the track expressed in the U.S. Army UAS Roadmap<sup>4</sup>. Even though developmental timelines will probably slip, progress is being made much along the lines forecast by the U.S. Army in 2010.

*“The capability to fly through urban canyons and deliver supplies and evacuate wounded is great stuff...we should do this. Please get on my calendar and come out and brief me on your program’s status.” (Maj. Gen. Robling, USMC, CG 3<sup>rd</sup> Marine Air Wing, AUVSI USIC, San Diego, CA, October 2007)*

## 2.3 REPRESENTATIVE UNMANNED AIRCRAFT SYSTEMS

### 2.3.1 Basic Considerations

The basic qualifiers<sup>5</sup> used to determine which UAVs are or could be suitable for the above-described missions are:

<sup>4</sup> “Eyes of the Army – U.S. Army Roadmap for UAS Operations 2010 – 2035”.

<sup>5</sup> Any manned helicopter with a digital flight control system and autopilot can be modified for unmanned flight by modifying the flight control and autopilot software and adding a Command and Control (C2) system (e.g. UH-60 MIKE Upgrade Black Hawk) [this is a simplistic but accurate description]. Additionally, any manned helicopter with an autopilot can be modified for unmanned flight by modifying the autopilot, adding actuators to the mechanical, electric or hydraulic flight controls, and adding a C2 system (e.g. Boeing OH-6A to Unmanned Little Bird Configuration).

- Unmanned or optionally piloted air vehicles;
- VTOL capable;
- Footprint < H-60 Black Hawk helicopter (approximate);
- 1000 pound payload (excluding sensors and fuel); and
- Internal carriage (for sensitive medical supplies and casualties) with appropriate restraints (e.g. cargo tie-down straps and standard NATO litter tie-downs).

It must be noted that of all the VTOL UAVs described in this report, only one – the Israeli Urban Aeronautics “Air Mule” has been specifically designed for logistics and medical missions (i.e. resupply and MEDEVAC). All other VTOL UAVs are being, or have been, developed for ISTAR, utility, or cargo delivery missions. This is expected, as these are less challenging mission sets to design to and perform, compared to the very complex MEDEVAC and CSAR missions. In the longer term however, VTOL UAV will have the capability to perform MEDEVAC and CSAR missions as sensor technology, artificial intelligence, and computer processing speed improve and sensor and computer SWAP (size, weight and power) decrease.

One point must be made in this discussion, since two critical definitions are often confused:

- A) Digital flight controls systems refer to the digital data bus and flight control computer. These information systems manage the legacy control tube and hydraulic flight control system through trim actuators.
- B) Fly-by-wire systems utilize flight control computers as well, and therefore are digital, but they do not incorporate the use of legacy flight control tube technology and hydraulics. Rather, they employ the use of Linear Variable Differential Transducers (LDVTs) to move the control surfaces. These systems have greater responsiveness, less weight, and improved handling qualities.

This differentiation is critical, as it is our conclusion that any UAV to be used in the CASEVAC role should be fly-by-wire, rather than just using digital flight controls.

### **2.3.2 Current/Developmental<sup>6</sup> VTOL UAS**

#### **A) Unmanned Little Bird (ULB)**

Manufacturer:	Boeing
Country of Origin:	USA
Payload:	1200 LB
Range:	260 NM
Speed:	119 KTS
Rotor Diameter:	26 FT 4 IN
Service Ceiling:	15,000 FT
Internal Carriage:	Possible with cabin modification
Status:	Manned versions are in service and 2 unmanned versions exist

---

<sup>6</sup> “Developmental” means “in developmental flight test” for the purposes of this document.





**Figure 2-1: Boeing Unmanned Little Bird (ULB).**

- Notes: 1) The current ULB retains the manned version's cockpit and pilot/co-pilot seats which could be used to hold casualties. Additionally, the cockpit could be modified to accommodate one or more medical litters.
- 2) The U. S. Marine Corps used the ULB in their successful Limited Objective Experiment 3.3, June 2009 to explore the concept of unmanned CASEVAC.

**B) KMAX**

Manufacturer:	Kaman
Country of Origin:	USA
Payload:	6,855 LB
Range:	267 NM
Speed:	80 KTS
Rotor Diameter:	48 FT 3 IN
Service Ceiling:	29,000 FT
Internal Carriage:	Possible with cabin modification
Status:	In service commercially





**Figure 2-2: Kaman KMAX.**

- Notes: 1) The U.S. Marine Corps has deployed KMAX during Operation ENDURING FREEDOM in Afghanistan to perform a UAS air cargo delivery and to assess the Cargo Resupply UAS delivery concept and the KMAX VTOL UAS system (November 2011 – May 2012). The U.S. Marine Corps envisions a follow-on program of record based on lessons learned from this assessment.
- 2) This KMAX UAV retains the manned version's cockpit and pilot's seat which could be used to hold supplies or a casualty. Additionally, the cockpit could be modified to accommodate one or more medical litters.

## C) **FIRE-X**

Manufacturer:	Northrop Grumman / Bell Helicopter
Country of Origin:	USA
Payload:	3,000 LB
Range:	530 NM
Speed:	133 KTS
Rotor Diameter:	35 FT
Service Ceiling:	20,000+ FT
Internal Carriage:	Yes (1 – 4 litters depending on cabin configuration)
Status:	In development, including developmental flight testing on company Internal Research and Development (IR&D)



Figure 2-3: Northrop Grumman / Bell Helicopter FIRE-X.

Note: This is a modified Bell 407 manned helicopter which is in development and flight test.

D) **AirMule**

Manufacturer:	Urban Aeronautics
Country of Origin:	ISR
Payload:	1050 LB
Range:	600 NM
Speed:	100 KTS
Rotor Diameter:	NA (ducted fan) Fuselage is 22 FT x 7 FT x 6 FT
Service Ceiling:	12,000 FT
Internal Carriage:	Yes – 2 litter patients
Status:	In development, including developmental flight test



Figure 2-4: Urban Aeronautics "AirMule".

Note: The AirMule is designed to be an actual medical evacuation platform as well as a Logistics, CASEVAC, MEDEVAC, and CSAR platform.

## 2.3.3 Future or Proposed VTOL UAS<sup>7</sup>

### A) AgustaWestland Optionally Manned Demonstrator “RUAV”

Manufacturer:	AgustaWestland
Country of Origin:	IT/UK
Payload:	TBD
Range:	TBD
Speed:	TBD
Rotor Diameter:	TBD
Service Ceiling:	TBD
Internal Carriage:	Yes
Status:	First developmental test flight scheduled for 2012



**Figure 2-5: AgustaWestland RUAV.**

Note: This demonstrator is in development, based on the PZL SW-4 helicopter.

### B) U.S. DARPA Transformer (TX) “Flying Car” Road Capable VTOL/STOVL UAS Program

Manufacturer:	AAI Corp.
Country of Origin:	USA
Payload:	1,000 LB
Range:	250 NM
Speed:	130 KTS (airborne) / 60 MPS (ground)
Rotor Diameter:	50 Ft
Service Ceiling:	10,000 FT
Internal Carriage:	Yes (1 – 4 passengers, or 1 – 3 passengers and 1 – 2 litters)
Status:	In development, first flight scheduled for 2015

<sup>7</sup> These UAS may either be in development, but have not yet flown, or are conceptual, but have some engineering analysis behind them.



**Figure 2-6: U.S. DARPA Transformer (TX) “Flying Car” / AAI.**

Note: This vehicle employs Carter Aviation Technologies’ Slowed Rotor/Compound Gyroplane technology for vertical or short take-off and short landing role operations.

**C) U.S. DARPA Transformer (TX) “Flying Car” Road Capable VTOL UAS Program**

Manufacturer:	Lockheed Martin
Country of Origin:	USA
Payload:	1,000 LB
Range:	250 NM
Speed:	126 KTS (airborne) / 80 MPH (ground)
Rotor Diameter:	NA (ducted fan)
Service Ceiling:	10,000 FT
Internal Carriage:	Yes (1 – 4 passengers, or 1 – 3 passengers and 1 – 2 litters)
Status:	In development, first flight scheduled for 2015



**Figure 2-7: U.S. DARPA Transformer (TX) “Flying Car” / Lockheed Martin.**

**D) Piasecki Aircraft X-49A “SpeedHawk” Vectored Thrust Ducted Propeller (VTDP) Compound Helicopter**

Manufacturer:	Piasecki Aircraft
Country of Origin:	US
Payload:	6800 LB
Range:	450 NM
Speed:	207 KTS

Rotor Diameter:	53 FT 3 IN
Service Ceiling:	10,000+ FT
Internal Carriage:	Yes
Status:	In development; First flight was in June 2007 and the Phase 1 flight test envelope expansion program is complete



Figure 2-8: Piasecki “Speed Hawk”.

### E) Sikorsky X-92 “Raider” Compound Helicopter

Manufacturer:	Sikorsky
Country of Origin:	US
Payload:	1,200 LB
Range:	570 NM
Speed:	200+ KTS
Rotor Diameter:	33 FT
Service Ceiling:	10,000+ FT
Internal Carriage:	Yes
Status:	In development, first flight TBD



Figure 2-9: Sikorsky "Raider".

**F) Advanced Tactics Black Knight Multi-Mission Medical and CASEVAC UAV/UGV**

Manufacturer:	Advanced Tactics, Inc.
Country of Origin:	US
Payload:	1,000+ LB
Range:	TBD
Speed:	TBD
Rotor Diameter:	TBD
Service Ceiling:	10,000+ FT
Internal Carriage:	Yes
Status:	In development, First flight scheduled for 1 <sup>st</sup> or 2 <sup>nd</sup> QTR 2012



Figure 2-10: Advanced Tactics "Black Knight".



### 2.3.4 Notional VTOL UAS Concepts

There are many other conceptual VTOL UAS being presented by industry and academia throughout the NATO Nations which theoretically could perform the medical missions addressed in this report. Unfortunately, a number of developers specifically requested to NOT be included in this report for proprietary reasons, and developmental/performance data is not readily available for these concepts.

#### A) Dragonfly Pictures DP-5XT

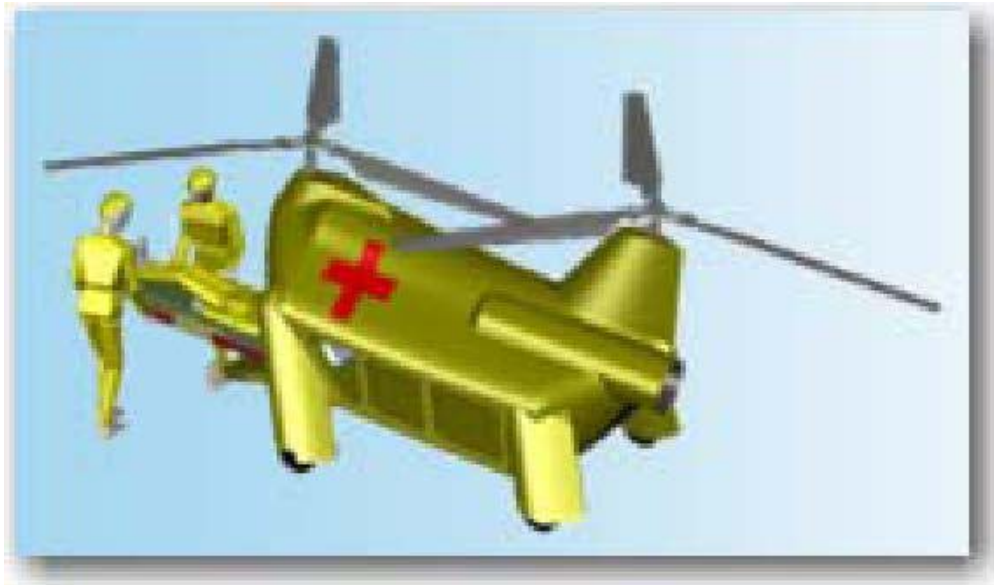


Figure 2-11: Dragonfly Pictures DP-5XT.

#### B) Piasecki Aircraft Combat Medic UAS



Figure 2-12: Piasecki "Combat Medic".

## 2.3.5 Enabling Technologies and Artifacts

UAS technology, as well as related and enabling technologies, is advancing rapidly. It is commonly believed unmanned systems can provide “*Revolutionary*” capability while being developed in an “*Evolutionary*” manner. Consequently, identifying UAS missions and tasks is often a case of “not knowing what we don’t know”.

### 2.3.5.1 Command and Control Architecture

There are no known VTOL UAS for Medical Mission architectures. Almost all existing UAS architectures are for fixed-wing UAS and for ISTAR and Strike missions, which are significantly different from those for medical missions such as urgent resupply or CASEVAC. The only known VTOL UAS architecture is for the U.S. Navy’s Fire Scout shipboard UAS, which is an ISTAR platform. The C2 architecture being used in Afghanistan today by the U.S. Marine Corps as they conduct their Cargo Resupply UAS assessment is the closest to meeting VTOL UAS for Medical Mission needs. A specific VTOL UAS for Medical Missions architecture must be developed before any capability assessment can begin.

### 2.3.5.2 Concept-Of-Operations (CONOPS)

A CONOPS for VTOL UAS Medical Missions is necessary before an operational architecture can be developed. There are only three known VTOL UAS CONOPS that are potentially applicable<sup>8</sup>:

- *Combat Medic UAS Concept-of-Operations* (draft) developed by the U.S. Army Telemedicine and Advanced Technology Research Center (TATRC). This CONOPS was developed from the U.S. Navy Space and Naval Warfare Systems Command’s “Nightingale” feasibility study investigating autonomous, man-rated, VTOL UAS for multi-purpose transport – logistics, CSAR and MEDEVAC.
- *Combat Medic UAS Concept-of-Operations* developed by Piasecki Aircraft as part of their Combat Medic UAS Small Business Innovative Research project performed for U.S. Army TATRC.
- *Joint Unmanned Casualty Evacuation (JUMC) Concept-of-Operations*, developed under the auspices of the U.S. Joint Forces Command Joint Medical Distance Support and Evacuation (JMDSE) Joint Capability Technology Assessment (JCTD). This CONOPS is largely based on the TATRC CM UAS CONOPS mentioned above, and is the CONOPS selected for evaluation by this RTG (see Chapter 4).

### 2.3.5.3 Standards

There are sufficient development and performance standards for VTOL UAS, such as the U.S. Joint Architecture for Unmanned Systems<sup>9</sup> and NATO STANAG 4586<sup>10</sup>. Additionally, there are Airworthiness standards for aircraft, including rotary wing and UAV, and for the equipment they carry. Further, the U.S. Food and Drug Administration (FDA) and other national/international medical regulatory authorities have requirements for portable en route patient care systems. However, **THERE ARE NO COMPREHENSIVE MEDICAL OR SAFETY STANDARDS BASED ON PHYSIOLOGICAL STATUS OR CASUALTY CONDITION WHICH HAVE BEEN PROMULGATED ANYWHERE IN THE WORLD FOR TRANSPORTING CASUALTIES ABOARD MANNED OR UNMANNED VTOL AIRCRAFT.** This study is a first step towards developing these standards based on research, modeling and simulation, and analysis.

<sup>8</sup> It must be noted that none of these are approved “operational concepts” at this time, and are conceptual only.

<sup>9</sup> Society of Automotive Engineers, “Joint Architecture for Unmanned Systems”.

<sup>10</sup> “Standard Interfaces of UAV Control Systems (UCS) for NATO UAV Interoperability”.



#### **2.3.5.4 Requirements Documents**

There are no known VTOL UAS requirements documents for Medical Missions from any NATO member Nation except the U.S. The U.S. Army published a document in 2010, which is now in U.S. joint staffing as of January 2012 for publication as a Department of Defense policy document. A top-level requirements document, it specifically notes that:

*“...Unmanned Systems also enable sustainment and force support operations through the automation of critical missions, including: assured mobility, transportation, distribution, maintenance, explosive ordnance disposal, communications, and health services.... Unmanned Systems force health protection includes battlefield extraction and transport.... Force health protection capability gaps include the inability to safely diagnose, recover, and transport casualties with en route care from areas where manned systems are denied entry or unavailable.... The Force lacks sufficient autonomous ground, air, and maritime logistics and distribution capability to provide responsive, assured supply and services to highly dispersed units across the extended OE operational environment. The Force lacks the capability to provide health services or mortuary affairs services where manned systems are denied entry or unavailable....”<sup>11</sup>*

While this “Initial Capabilities Document (ICD)” is a critical first step, more detailed requirements are required from the operating forces before any formal acquisition programs can be initiated.

#### **2.3.5.5 Air Vehicles**

There are only a few VTOL UAVs currently available capable of performing urgent medical item resupply, short range casualty extraction, CASEVAC, TACEVAC and CSAR – they are listed above (see Section 2.2.4). There is no fielded VTOL UAV currently capable of performing the MEDEVAC mission. The first VTOL UAV specifically designed to be capable of performing the MEDEVAC mission is being developed by Urban Aeronautics in Israel. Further, all the current VTOL UAS which are urgent medical item resupply/ short range casualty extraction / CASEVAC / or CSAR capable will require cabin modifications to accommodate one or more NATO standard litters.

#### **2.3.5.6 Man-Rating**

A much debated hot topic that has not been resolved is whether these VTOL UAS should be fully “man-rated” as are manned aircraft. By definition, “man-rated” means “operated or crewed” like a ship or an armored vehicle, and the casualties are not going to be flying the UAS, obviously. On one hand, “man-rating” adds a level of reliability and safety that may be desired. But on the other hand, “man-rating” an aircraft is expensive and UAS are supposed to be cheaper than manned aircraft. The conundrum is fairly obvious and needs to be addressed. Perhaps there’s a “middle ground” between “man-rated” and “you get what you get” – perhaps “Humans as Cargo (HAC)”?. This policy-level issue is going to have to be decided by the aircraft development/procurement communities, as its resolution is far beyond the capabilities of this RTG.

#### **2.3.5.7 Sensors**

Current electro-optical, infrared, laser and radar sensors are capable of providing the necessary field-of-view, scan rate, resolution and range for VTOL UAS autonomous take-off, en route flight and obstacle avoidance, and landing site selection and landing. Ideally their SWAP should be reduced, as should their cost and this is expected to occur within the next few years.

---

<sup>11</sup> “Initial Capabilities Document (ICD) for Unmanned Systems (Air, Ground, Maritime)”.

### **2.3.5.8 Command and Control (C2)**

Current command and control capabilities should be sufficient to conduct the targeted mission set, especially for UAS mission planning and flight. However, integrating the VTOL UAS C2 architecture and system with the requisite medical C2 architecture and system has yet to be demonstrated and will require programmatic, technical and operational effort and resources. This includes Architecture and CONOPS development as described above.

### **2.3.5.9 Autonomy**

Full VTOL UAS autonomous operations are years away for technical, programmatic and operational reasons. However, autonomous VTOL UAS operation has been demonstrated by Piasecki Aircraft<sup>12</sup>. This effort incorporated autonomous take-off, en route waypoint navigation based on GPS coordinates and onboard LADAR (Laser Detection and Ranging) sensors, Landing Zone (LZ) selection and rejection (based upon detected obstacles in the LZ), and the selection of another, more suitable LZ, and autonomous landing. This was a first technical demonstration as KlearPath™ is only at Technology Readiness Level 5 – 6. Additional development and demonstration in more operationally realistic environments is required (e.g. different weather conditions, varying terrain, beyond line-of-sight C2, night/low visibility conditions).

### **2.3.5.10 Medical Devices for en route Care**

By the nature and definition of casualty extraction or CASEVAC, en route medical care is not required, but is obviously very nice-to-have and should be used if available. On the other hand, CSAR and MEDEVAC will require en route casualty care by doctrine. This can be accomplished two ways:

- 1) Have medical personnel accompany the casualty on the UAS (this obviously may partially negate the advantages of employing an “unmanned” system in the first place); or
- 2) Develop an autonomous en route critical care system to monitor, record and transmit status (via UAS C2 system), and provide some level of care, perhaps directed by medical personnel on the ground (again, via the UAS C2 system) – i.e. a closed-loop, portable, critical care device.

This topic is discussed in more detail in Chapter 7 and Annex D.

### **2.3.5.11 Summary of Mission Enablers**

The following table scores the current status of VTOL UAS for Medical Missions enablers as determined by the NATO HFM-184 Technical Panel membership and by their discussions with subject-matter experts from academia and industry.

---

<sup>12</sup> See the KlearPath™ video at <http://www.piasecki.com/cmuav.php>.

**Table 2-1: Mission Enablers Current State of the Art.**

Architecture	<b>R</b>	Air Vehicle	<b>Y</b>
Concept of Operations	<b>G</b>	Sensors	<b>G</b>
Standards	<b>G</b>	Command and Control	<b>Y</b>
Requirements Documents	<b>Y</b>	Autonomy	<b>Y</b>
International Agreements and National/Defense Policy	<b>R</b>	Medical Devices for en route Care	<b>Y</b>
Doctrine	<b>R</b>		

**KEY:**

<b>Green:</b>	Requisite capability exists.
<b>Yellow:</b>	Requisite capability exists but requires further development before fielding.
<b>Red:</b>	Requisite capability does not yet exist for VTOL UAS Medical Missions.

## 2.3.6 Ongoing Related Efforts

As this is written, there are numerous ongoing related efforts which may affect the future utility of the UAV CASEVAC Concept, which are detailed in the following sub-sections.

### 2.3.6.1 Autonomous Aerial Cargo/Utility System (AACUS) Innovative Naval Prototype

Program Office: U.S. Office of Naval Research

Timeframe: FY12 – 16

Goals: The primary focus of the Autonomous Aerial Cargo/Utility System (AACUS) is the development of advanced autonomous capabilities to enable unmanned and optionally manned VTOL air systems to be fully capable of affordable and reliable rapid response cargo delivery to distributed small units under demanding conditions. AACUS encompasses the development and implementation of VTOL-based obstacle detection and avoidance, as well as autonomous unprepared landing site selection and dynamic execution to the point of landing with goal-based supervisory control by any field personnel with no special training. These capabilities, expected to form part of an open architecture framework in order to be used across different VTOL platforms, should have sufficient reliability to be entrusted with precision cargo delivery and evacuating human casualties from remote sites.

### 2.3.6.2 Autonomous Technologies for Unmanned Aerial Systems (ATUAS) Joint Capability Technology Demonstration (JCTD)

Program Office: U.S. Army Aviation Applied Technology Directorate

Timeframe: FY12 – 14

**Goals:** The ATUAS JCTD will integrate a series of previously demonstrated technologies and demonstrate both single vehicle intelligent operations as well as multi-vehicle teaming operations. The JCTD will demonstrate autonomous precision delivery and retrograde to and from a forward point of need in operationally relevant conditions. It will address capabilities identified in the U.S. Central Command (USCENTCOM) Joint Urgent Operational Needs Statement (JUONS) as objective level requirements and will support the initial NAVAIR/USMC Immediate Cargo UAS (ICUAS) deployment. The unmanned team will use high level autonomy to: autonomously deliver multiple loads; conduct materiel retrograde; maintain situational awareness with feedback to the control station; autonomously adjust to the changing mission; provide multiple control station concepts including dismounted command and control, with capability to transfer control between operators; and autonomously identify optimum load delivery locations. The system will be capable of operations in adverse weather, extreme temperature and high elevations.

## 2.3.6.3 Medium Range Multi-Purpose (MRMP) VTOL UAS

**Program Office:** U.S. Army Program Office Unmanned Aircraft Systems – This is a coordinated effort with the U.S. Navy Naval Air Systems Command

**Timeframe:** FY12 – 14 +

**Goals:** PM UAS is seeking an MRMP VTOL UAS to leverage existing, proven technology solutions from industry which address the following areas: Primary Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) roles and additional capabilities (e.g. resupply, weapons, high-levels of autonomy, teaming, safety, redundancy, maintainability, reliability, survivability, airworthiness, security, deployability).

## 2.3.6.4 Medium Range Maritime Unmanned Aerial System (MRMUAS)

**Program Office:** U.S. Navy Naval Air Systems Command – This is a coordinated effort with the U.S. Army Program Office for Unmanned Aircraft Systems

**Timeframe:** FY16 – 19+

**Goals:** MRMUAS addresses the need to conduct persistent airborne ISTAR missions in permissive or semi-permissive environments from sea-based platforms. MRMUAS alternatives should also meet the Army and Marine Corps needs for an unmanned aircraft with greater range, endurance, and payload capacity than today's small tactical UAVs, while offering the operational flexibility of launch and recovery from austere and unimproved sites. The Navy is specifically interested in the following areas:

- a) Small-deck ship based, persistent ISR UAS platforms;
- b) Integrating multiple, modular payloads onto UASs;
- c) Simultaneously controlling multiple UASs at Beyond-Line-Of-Sight (BLOS) ranges for both aircraft Command and Control (C2) as well as payload data; and
- d) Rapidly and effectively processing and disseminating ISR data collected from sea-based UAS platforms.

## **2.4 SUMMARY**

Thus, it appears that from a technical viewpoint, there are no real stumbling blocks to the development of this capability. There is a requirement for further development, but in general the technology to accomplish this mission already exists.



## **Chapter 3 – CURRENT NATO DOCTRINE AND POLICY, AS IT AFFECTS THE CONCEPT OF CASUALTY EVACUATION VIA UAVs**

### **3.1 INTRODUCTION**

Any use of a new modality for casualty care in the NATO environment must take into account current and developing doctrine. Therefore, a comprehensive review of NATO medical doctrine and policies which might affect this concept was undertaken. We have found that there are currently no NATO medical doctrinal documents which directly address this issue, though likewise there is nothing found in current NATO medical doctrine which would preclude the future use of UAVs for CASEVAC, when appropriate.

### **3.2 KEY NATO DOCTRINAL DOCUMENTS**

#### **3.2.1 MC 326/3 (NATO Principles and Policies of Medical Support)**

The keystone document for NATO medical care sets forth the basic requirements for medical care in the NATO environment. Foremost among these is the concept that medical care, when available, should be of the highest possible quality, given the military setting, and should be such as “to achieve outcomes of medical care equating to best medical practice<sup>1</sup>.” This clearly mandates that MEDEVAC of casualties on fully equipped platforms with en route care available should whenever possible be used in preference to CASEVAC. However, there is nothing in this document which discusses what capability to use, when the decision to use CASEVAC has been made, for whatever reason.

This same document also discusses many of the changed strategic parameters which mandate consideration of new mechanisms for providing medical care<sup>2</sup>, and demands that “Clinical need is to be the principal factor governing the priority, timing and means of a patient’s medical care and evacuation<sup>3</sup>.” The demand for rapid evacuation is noticeable, particularly in light of the new 10-1-2 medical timeline doctrine.

While most of the discussion of evacuation found in MC 326/3 refers to “medical evacuation”, other resources are more inclusive, referring only to “evacuation”, which term seems to be used in such a way as to include both MEDEVAC and CASEVAC.

#### **3.2.2 AJP-4.10 (B) (“Allied Joint Medical Support Doctrine” – Draft)**

Elucidates and expands many of these concepts. It begins by pointing out the shortfalls in medical capabilities and support which are now available for NATO missions<sup>4</sup>, and the fact that these shortfalls make the provision of medical support on operations even more challenging than in the past. The projected difficulties of complying with all mandated criteria are noted, and it is clearly stated that “due to the environment and conditions the procedures will not always be the same as practiced during peacetime<sup>5</sup>.” Though this draft

---

<sup>1</sup> MC 326/3, para 3.3.

<sup>2</sup> MC 326/3, para 1.1.

<sup>3</sup> MC 326/3, para 3.5.

<sup>4</sup> AJP-4.10 (B) (Draft 2011), para 1004.

<sup>5</sup> AJP-4.10 (B) (Draft 2011), para 1021.



document implicitly assumes that all evacuation will be “medical evacuation” as defined by NATO, it explicitly states that availability of such capabilities may be limited or delayed for operational or materiel reasons, and thus implicitly demands that other capabilities must be considered in medical planning. More detailed doctrine for Medical Evacuation is found in Chapter 3 of AJP-4.10 (B), with a reference to AJMEDP-2. AJP-4.10 (B) (Draft) notes that “The medical evacuation concept described in this chapter does not impose a unique mandatory evacuation system on Nations<sup>6</sup>.” It thus implicitly authorizes other forms of evacuation, so long as they can meet the timeliness goals of this document.

It is correctly noted that neither MC 326/3 nor AJP-4.10 (B) (Draft) directly address the issue of “Casualty Evacuation”, as defined in AMEDP-13(A). However, CASEVAC (as distinguished from MEDEVAC) is currently found in NATO doctrine, as well as in many national doctrines.

### **3.2.3 AJMEDP-2 (“Allied Joint Doctrine for Medical Evacuation”)**

Is the highest level of NATO doctrine currently addressing the concept of CASEVAC. This document notes that: “It is important to state here that the term Casualty Evacuation (CASEVAC) is used by some Nations, but when used it means unplanned movements of casualties without designated medical support or opportunistic movements by available medical personnel. This type of movement will inevitably occur...”<sup>7</sup> It then goes on to clearly distinguish CASEVAC and MEDEVAC, and to note that CASEVAC is not subject to medical planning strictures, and will not affect the medical footprint. This document clearly states that CASEVAC (the use of non-medical vehicles for evacuation, not under medical control, and without care en route) will happen, and by definition it is not under medical control. Thus, it is evident that any specific proposed policies for the use of UAVs in CASEVAC will not be found in medical doctrine. However, it is certainly appropriate for medical guidance as to the clinical aspects of such use to be given by medical personnel to line commanders, as operational medical personnel do in many other fields which are line commander responsibilities, e.g. cold weather injury prevention, altitude sickness prevention, food and sanitation, etc. Since most CASEVAC traditionally takes place in the far-forward areas, and is thus national rather than multi-national in nature, it is appropriate for this concept to be dealt with more definitively in national (rather than NATO) doctrinal publications, which it is.<sup>8</sup>

### **3.2.4 STANAG 2087 (“Medical Employment of Air Transport in the Forward Area”)**

Also addresses CASEVAC as a concept, though only to note that “Operational situations may preclude use of aeromedical escorts; this movement of patients without medical supervision – also referred to as CASEVAC – should only be applied in extraordinary circumstances.”<sup>9</sup> The RTG agrees with this concept, but notes that the use of UAVs to provide such services is not prohibited, and that it is assumed by this STANAG that such non-medical transportation means will be used occasionally during combat.

### **3.2.5 AMEDP-11 (“NATO Handbook on Maritime Medicine”)**

Seems to use the terms “CASEVAC” and “MEDEVAC” interchangeably, but notes clearly that what it is talking about may or may not include care in flight<sup>10</sup>, thus emphasizing the potential utility of CASEVAC, depending on operational requirements and casualty needs.

---

<sup>6</sup> AJP-4.10 (B) (Draft 2011), para 3002.

<sup>7</sup> AJMEDP-2, Para 0103-1.

<sup>8</sup> Several of these are listed in the Reference list.

<sup>9</sup> STANAG 2087, Ed 6, para 14 and Ed 7 SD1, para 6.

<sup>10</sup> AMEDP-11 (A), para 19.4.

### **3.2.6 AMEDP-38 (“Medical Aspects in the Management of a Major Incident / Mass Casualty Situation”)**

Deals with major medical incidents and mass casualty situations, which may be closely analogous to some of our vignettes for possible use of UAVs in the CASEVAC role. While this AMEDP does not specifically discuss the use of UAVs in this role, it clearly gives doctrinal support to the use of non-medicalised vehicles for evacuation in emergencies, i.e. CASEVAC<sup>11</sup>.

The COMEDS Liaison Officer has specifically included the concept of CASEVAC by UAVs in exemplary input to the Military Committee’s Long Term Capability Requirement M.03<sup>12</sup>. Therefore, at the highest level of NATO medical authority, consideration of this concept is considered appropriate.

### **3.2.7 International Humanitarian Law**

Also in the area of doctrine, we feel that it is important to mention the Law of Warfare and Customary Humanitarian Law. Several opponents to the use of logistics UAVs for casualty evacuation have raised various objections which they state are based on the Geneva Conventions. We have carefully reviewed the entire corpus of the Geneva Conventions<sup>13</sup>, including the Additional Protocols of 1977<sup>14</sup>. We find nothing in the Conventions which would preclude the use of UAVs in this context – in fact the Conventions make no mention of requirements for what vehicles may be used for evacuation purposes. The primary requirement is that “the wounded and sick shall be collected and cared for”<sup>15</sup>, without reference to the mechanisms for accomplishing that goal. Further elucidation of this principle demands that the wounded and sick “shall be respected and protected in all circumstances... without any adverse distinction founded on [any criteria other than medical needs].... They will not be left without medical assistance and care.” Further, there is a restriction that only urgent medical reasons will authorize priority in the order of treatment to be administered<sup>16</sup>. Generally, the Conventions demand that medical care given to civilians and enemy casualties be the same as that available to friendly casualties – this implies that if UAVs are used for CASEVAC for own forces, they can also be used for wounded enemy personnel.

One argument that has been made against the occasional use of logistics UAVs for CASEVAC is that the vehicles would not be able to benefit from the use of the Geneva Protective Marking. This statement is true – however, the same can be said about any evacuation vehicle which is not fully dedicated to ambulance use, including many currently in use in NATO operations (e.g. those CH-47s used by the UK MERT teams and the USAF “Pedro” aircraft). In fact, it would be a war crime under the conventions to so mark a “dual-use” vehicle<sup>17</sup>, one which is not “exclusively employed for the removal of wounded and sick, and for the transport of medical personnel and equipment.” The use of the Geneva protective symbol when authorized is optional,

---

<sup>11</sup> AMEDP-38, (Final Draft 2011), paras 0010 b (3) and 0013 i.

<sup>12</sup> COMEDS (LO)L(2010)0004.

<sup>13</sup> We have paid the most attention to the 1949 First Geneva Convention (“For the Amelioration of the Condition of the Sick and Wounded in Armed Forces in the Field”) as being the most relevant, with secondary attention paid to the Second, Third, and Fourth Geneva Conventions.

<sup>14</sup> We have also reviewed the Additional Protocols simply for completeness, in spite of the fact that they have not been accepted by all NATO members, and thus can not be considered part of the body of the “customary law of war” in the NATO context.

<sup>15</sup> Geneva I, Article 3, para (2).

<sup>16</sup> Geneva I, Article 12.

<sup>17</sup> Geneva I, Article 36.

according to the Commander's discretion<sup>18</sup>, and its lack would not inherently preclude the use of the vehicle for casualty evacuation. We note that currently, the only major group of aircraft so marked within NATO are those operated by the U.S. Army. Most Nations and services seem to have agreed that Red Cross markings on aircraft may be nice to have, but are not required by law or international agreement.

### **3.2.8 Other Documentation**

As far as we have been able to determine, there are no known international agreements, treaties or individual NATO national policies precluding the employment of VTOL UAV for medical missions. There are requirements – real and implied – to provide the best level of care possible (as noted above), which may conceivably in the future demand evacuation by VTOL UAS because of the weather, threat, geographic location (e.g. small LZ), manned aircraft unavailability, or other operational reasons.

The one known exception to this lack of relevant doctrine is the U.S. Army Medical Department Center and School, which considers "... *the use of unattended robotic platforms for casualty evacuation (is) unacceptable.*"<sup>19</sup> However, CASEVAC is not a U.S. Army "medical mission" – only MEDEVAC is. CASEVAC is an "operational mission" authorized and directed by the operational commander, not by the medical commander. Therefore, although we have carefully discussed this objection, we find it not directly relevant to the issue of CASEVAC via UAVs.

The remaining U.S. Services and the U.S. Special Forces Command (USSOCOM) have no policies which we have been able to locate precluding the use of VTOL UAS for any missions, medical or otherwise. This may be because the U.S. Army is the only U.S. Service with a dedicated MEDEVAC capability. The other Services and USSOCOM either use the Army's MEDEVAC capability or a CASEVAC capability (i.e. "... unregulated movement of casualties ..." <sup>20</sup> or a "lift-of-opportunity")<sup>21</sup>.

## **3.3 RTO INTEREST IN UAVS**

Various RTGs under the auspices of the Research and Technology Organisation have previously considered various aspects of the use of UAVs, demonstrating a very real interest in various uses for this technology, though none have directly addressed the potential medical uses of these aircraft. These include:

- RTO-AG-300-V27 "[Unique Aspects of Flight Testing Unmanned Aircraft Systems](#)";
- RTO-TR-AVT-138 "[Nanotechnology for Autonomous Vehicles](#)";
- RTO-EN-SCI-208 "[Advanced Automation Issues for Supervisory Control in Manned-Unmanned Teaming Missions](#)";
- RTO-MP-SCI-202 "[Intelligent Uninhabited Vehicle Guidance Systems](#)";
- RTO-TR-SCI-144 "[Integration of Systems with Varying Levels of Autonomy](#)";
- RTO-TR-SCI-124 "[Architectures for the Integration of Manned and Unmanned Air Vehicles](#)";

---

<sup>18</sup> STANAG 2931.

<sup>19</sup> "Use of Robotic Vehicles for CASEVAC", U.S. Army AMEDD Center and School memo, dated 7 June 2006, and verified in a second AMEDD memo, dated 20 November 2009.

<sup>20</sup> U.S. Joint Publication JP 1-02, "Department of Defense Dictionary of Military and Associated Terms".

<sup>21</sup> The USAF CSAR system also provides evacuation on call, with care in flight provided by Paramedics, but since this system is not under medical control, it is categorised as "CASEVAC" as contrasted to "MEDEVAC".

- RTO-MP-AVT-146 “Platform Innovations and System Integration for Unmanned Air, Land and Sea Vehicles”;
- RTO-MP-AVT-145 “UAV Design Processes / Design Criteria for Structures”;
- RTO-EN-SCI-175 “System Control Technologies, Design Considerations and Integrated Optimization Factors for Distributed Nano UAV Applications”;
- RTO-MP-HFM-135 “Human Factors of Uninhabited Military Vehicles as Force Multipliers”; and
- RTO-MP-SCI-202 “Intelligent Uninhabited Vehicle Guidance Systems”.

### 3.4 SUMMARY

In summary, there are no known doctrinal issues regarding the use of VTOL UAS for medical missions which we have been able to find in any NATO Nation, with the single exception of the U.S. Army Medical Department, as described above. Having said that, there will certainly be doctrinal changes required before VTOL UAS can be viably employed operationally. This is true for all NATO member Nations, and for the Alliance as a whole. Such doctrinal changes are commonplace as new capabilities are fielded, and their necessity in the case of UAV CASEVAC is not surprising.

It is not surprising that NATO and national doctrine do not currently directly address the use of UAVs for CASEVAC. At the current time, there are no UAVs deployed in any of our national forces which are suitable for use in CASEVAC. The NATO Joint Capability Group Unmanned Aircraft Systems And Joint Unmanned Aircraft Systems Panel (JCGUAS/JUASP), though aware of the concept and the work of RTG-184, currently has no work ongoing to develop the concept or to investigate it, primarily due to the non-availability of suitable airframes, though they have just recently (March 2012) begun consideration of Logistics/Cargo UAVs. The majority of the work of this group and its two predecessors has been with regard to Fixed Wing UAVs, primarily for the ISTAR or armed attack roles. Inasmuch as the logistics UAVs which might be suitable for use in this role do not yet exist in an operational setting, the JCGUAS/JUASP has not paid any significant attention to this potential usage, though their newly created Terms of Reference certainly give them authority and scope to consider this new area, and to input the future use of UAVs for CASEVAC into NATO doctrine. This group had planned to consider a draft plan for Cargo UAVs in the Spring of 2012, but this document was not discussed at their meeting in March 2012. Some of their doctrinal documents, such as the UAV Pilot Requirements and Training Standards documents<sup>22</sup>, and the definitions of UAV by size and flight parameters, will eventually apply to the various uses of these logistics aircraft. Interestingly, a draft of STANAG 2289 does include a brief mention of their potential use in Combat Search and Rescue and potentially in Evacuation Operations<sup>23</sup>. This reference seems to primarily envision the use of UAVs in searching for the casualties, rather than carriage of them, but the inclusion of these topics clearly indicates that new ways of using these vehicles in the medical realm are being considered by various groups. We note that the JCGUAS Program of Work for 2012 refers to several Long Term Capability Requirements (LTCRs) for which UAV CASEVAC (or at least UAV passenger carriage) would be relevant<sup>24</sup>. We recommend strongly that the items listed under LTCRs M-3 and L-9 be expanded to specifically mandate consideration of the issue of CASEVAC by UAS.

---

<sup>22</sup> STANAG 4670.

<sup>23</sup> STANAG 2289 (Study Draft), para 219.

<sup>24</sup> JCGUAS Program of Work 2012, para 3.1.

Thus, although no direct doctrinal approval for the use of UAVs as CASEVAC Platforms is found within NATO doctrine, there is likewise nothing in doctrine which would disapprove their use, if medically acceptable from a casualty safety standpoint, and when such use would be in the casualty's best interests.

As logistics UAVs capable of carrying casualties are fielded, it will become imperative that NATO and national doctrine be modified to discuss and to give guidance for such use. This will probably require amendments to AJP-4.10 (B) and AJMedP-2 at a minimum. If it becomes feasible to actually use such airframes for MEDEVAC purposes (i.e. to carry medical personnel and equipment to provide care in flight), it will be necessary to amend STANAG 2087 to include guidance on such use. Custodians for these documents are strongly encouraged to begin development of such doctrine now, rather than waiting until the aircraft are present on the battlefield. Those Nations which do not have doctrine expressly addressing the issue of CASEVAC may wish to consider development of such doctrine.

## **Chapter 4 – POTENTIAL MEDICAL CONCEPTS FOR USE OF UAVs IN CASUALTY EVACUATION**

### **4.1 INTRODUCTION**

After discussion with many potential users of this technology for casualty evacuation, we have attempted to synthesize some of their thoughts on this subject. A major study on potential uses for such aircraft was finalized in 2011 by the United States Joint Forces Command, from which this chapter has been heavily drawn<sup>1</sup>.

This chapter provides several possible scenarios for the potential use of UAVs in Casualty Evacuation (CASEVAC) within the NATO operational concept. We believe that each of these scenarios is fully in accord with current NATO doctrine (see Chapter 3). It is against these basic scenarios that RTG-184 has evaluated the potential for such use, and they provide a context for our evaluations of clinical safety and operational utility. It is evident that many potential users consider that there are operational gaps for which this technology is needed, and we have accepted that analysis. It is not our function to determine whether there are such operational gaps, but to accept the user community statement that these gaps exist. Therefore, a full gap analysis has not been carried out by this RTG. It is up to the Nations to determine whether or not UAVs will be used for these purposes, but our group has had to assume for purposes of discussion that such use is operationally realistic and might in the relatively near future become reality. Following discussions with experienced combat-experienced helicopter pilots and line commanders, the RTG has determined that in our opinion these scenarios are viable and serve to illustrate several potential uses of UAVs in casualty evacuation.

Though the bulk of current NATO combat operations are in Afghanistan (ISAF), these concepts are not restricted to use in current locations or operational missions. Afghanistan can serve as an excellent example of some of the problems that such a concept is designed to overcome, but should not be seen as the only potential theatre for its use.

### **4.2 NATO AND COALITION OPERATIONS**

The non-linear aspects of battlefields such as Afghanistan have increased the threat to aircraft crews and platforms conducting manned MEDEVAC and CASEVAC operations. This increased threat places additional lives at risk – not only are the casualties at risk, but so are the evacuation crews. Combat operations may be conducted in a variety of environments which are often characterized by rugged terrain and obstacles to ground vehicle transportation. Some missions can be conducted up to hundreds of kilometers from Forward Operating Bases (FOB) and medical care facilities with the only medical support available on scene being unit medics or fellow soldiers. Casualties who may not clinically need evacuation may nevertheless inhibit small unit operations, and the commander may need to evacuate them immediately for operational reasons. Furthermore, combat in urban environments has shown that moving a casualty can be difficult and time-consuming. Moving an individual only a few hundred yards can take an hour or more, as has clearly been shown by Israeli experience in the Lebanon War. The extended lines of communication between forces and their Forward Operating Bases (FOB), inclusive of MEDEVAC by aircraft, are at risk of enemy ambush or Improvised Explosive Device (IED) attack. The great risks to MEDEVAC and resupply operations in these environments have occasionally placed a tremendous strain on the use of dedicated air assets to support these operations.

---

<sup>1</sup> U.S. Joint Forces Command, “Unmanned Aerial System Casualty Evacuation Concept Of Operations And Safe Ride Standards (Draft).



#### **4.2.1 Concept Goals**

Herein we describe a generic capability and some potential scenarios for the employment of a utility or logistics UAV to improve casualty survivability in an operational environment. The employment of UAV CASEVAC as an “aircraft of opportunity” may in some circumstances provide more timely critical response than reliance on manned aircraft, reduce the threat to aircraft crews, and provide new capability to move a casualty to another location for treatment or for transfer to another vehicle for onward transport. Our goals in creating this document were to:

- Describe the concept of using UAV for CASEVAC to safely conduct timely transport from the point of injury to appropriate medical care;
- Establish broad guidelines for the appropriate use of UAV for CASEVAC; and
- Enhance casualty care and reduce mortality by evaluating the proper potential uses of UAV for CASEVAC.

It must be noted that this concept is for use in CASEVAC, and these scenarios do not include the potential use of UAV for MEDEVAC, which is covered elsewhere in this document.

#### **4.2.2 Concept Details**

Two specific medical missions which potentially could be supported by a logistics UAV include:

- Evacuation of casualties from Point Of Injury (POI) in denied areas for short-haul delivery (“over-the-hill”) to an appropriate point of care or to a more accessible location for transfer to manned evacuation assets; and
- Evacuation of personnel from POI to a medical capability which is not present at the POI.

Our concept describes a potential capability which could add additional capacity with reduced risk to piloted aircraft and their crews in the following environments:

- Operations in high threat areas, poor weather, hazardous terrain, and hostile environments;
- Units operating in dispersed or remote locations, to include maritime or Special Operations forces;
- Immature or developing theaters of operation; or
- Expeditionary operations which require a quick response globally.

#### **4.2.3 Application and Scope**

This chapter is limited to describing a generic capability for the employment of UAV for the first two above-listed missions. It neither recommends nor endorses any specific solution, but rather describes a desired generic “end-state” capability. It also highlights topics for further investigation and discussion. The fundamental principles, guidance and capabilities presented in this chapter could potentially support NATO operational commands or joint task forces. The principles, guidance, and joint capabilities described also may apply to combined operations. Currently, NATO has no developed doctrine, concepts, or plans to support unmanned evacuation (see Chapter 3), however, NATO Nations and partner Nations are actively experimenting with using UAVs for cargo delivery, some of the potential platforms for which could provide the most appropriate platforms for UAV CASEVAC in the near future. The technology research and development community is moving forward, and we have attempted to make use of their current and recent work in this arena.



## 4.2.3.1 Assumptions

Several assumptions must be made in any discussion of the appropriateness of using UAVs for casualty transport:

- That protocols will be established which define casualties who may and may not be safely evacuated on UAVs by NATO Forces.
- That UAVs considered for this purpose will be able to meet the same safety (crashworthiness) standards and operate with essentially the same flight parameters as currently-approved man-carrying Rotary Wing aircraft, when those standards are relevant to casualty survival.
- That adequate training will be available to provide an aid in correct selection or non-selection of UAVs for CASEVAC use and preparation of the casualty for evacuation. This must include decision-making training for commanders, advanced initial combat trauma care training, and operational safety training for all field personnel.

## 4.2.4 Operational Vignettes

The following vignettes represent potential scenarios involving the use of UAVs supporting combat operations through the provision of CASEVAC support. The following operational view is provided to show an overview of potential CONOPS considered by the RTG in development of its NATO Safe Ride Standards (see Chapter 6).

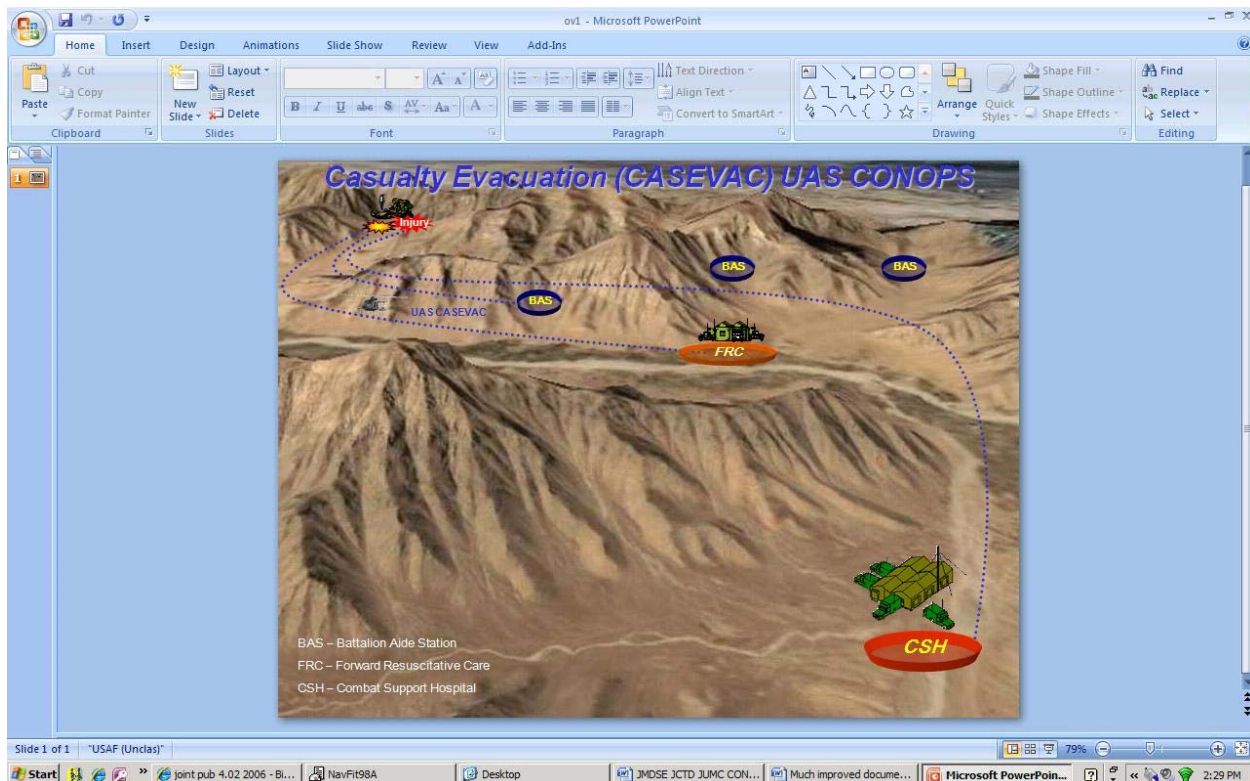


Figure 4-1: NATO Safe Ride Standards CONOPS.

- **Vignette #1 – CASEVAC / Casualty Extraction (“Over the Hill”):** An intense firefight is occurring in a town square where two friendly force infantry squads are receiving fire from all directions. Enemy forces control the areas surrounding the square and prevent reinforcement of the surrounded squads. Several RPGs explode as insurgents mount an assault and two Soldiers receive life-threatening injuries. No combat medics are available to these two squads. Situation reports detail the situation urgency and the requirement for immediate resupply and evacuation of the critically wounded Soldiers. Dedicated aeromedical evacuation assets are not available for 45 minutes at best. A cargo UAV delivers the urgently needed supplies. Fearing the wounded will not survive without immediate medical support, the on-scene commander decides to use the UAV to extract the casualties from the square and deliver them to a location where medics can stabilize their conditions, and prepare them for further evacuation.
- **Vignette #2 – Urgent CASEVAC:** A NATO Army aviation brigade is providing cargo UAV resupply in general support of allied forces. Flight operations are being conducted from an airfield located at a FOB which supports an Infantry Brigade Combat Team (IBCT) and its remote and widely dispersed battalions. The IBCT’s zone of action has a variety of terrain features which include flatland, dense forests, and mountainous areas (up to 12,000 ft MSL). Company teams operating in the mountainous areas require resupply by air, as there are no improved road networks and the area is susceptible to enemy ambush and IED attacks. A Company Observation Post (COP) is targeted by a mortar attack that results in severe injuries to two infantrymen. Combat Lifesavers administer first aid; the company’s medic has been killed; and the determination is made that the injuries require immediate medical support. An immediate MEDEVAC request is sent to the FOB; however, at the time of the request, all dedicated MEDEVAC platforms are conducting other missions, and cannot be made available for more than one hour, after refueling. Logisticians monitoring resupply missions note that there is a VTOL UAV delivering supplies to another company within 20 kilometers of the casualties, which is much closer to the COP than any manned aircraft currently available and which is suitable for casualty transport. Coordination with the aviation brigade reveals that the UAV has sufficient fuel to divert during its back haul flight and provide an aircraft of opportunity to the casualties. Mission change instructions are issued to the UAV operator who remotely programs the UAV for a landing at an LZ supporting the casualties’ location. On arrival at the LZ, the two litter casualties are secured aboard the UAV. The company radios that the casualties are secure and the area is clear for the UAV to depart. As the UAV departs the LZ, the UAV operator alerts the chain of command of the UAV mission status and provides the ETA to awaiting medical support at the FOB. This information is coordinated with the staff for reception and treatment of the inbound casualties.
- **Vignette #3 – Non-Emergency Casualty Extraction:** While patrolling an extremely rugged mountain pass area, a rifle platoon member severely sprains an ankle. His labored pace slows down movement of the platoon and hinders its potential for mission accomplishment. Concerned for the member’s injury and worried that the injury may be a liability if the unit has to rapidly maneuver; the platoon leader requests a CASEVAC. The decision is made to evacuate the injured member on the backhaul flight of an unmanned cargo aircraft which will rendezvous with the platoon for supplies, as the platoon leader receives orders to immediately move his patrol area 5 kilometers. Acknowledging the new patrol area, the platoon leader is relieved that the injured member has boarded the cargo UAV for evacuation to a supporting medical facility, and that without the hindrance of dealing with the casualty, his unit can proceed with its mission.

## Chapter 5 – MEDICAL/CLINICAL ASPECTS/STANDARDS FOR PUTTING PEOPLE IN UAVs

### 5.1 INTRODUCTION

The basic question with regards to the issue of moving casualties by air is that of clinical benefit or harm. Whatever the capabilities or limitations of the aircraft being considered, the first requirement is to determine whether the casualty's condition will allow him to be moved by this means. This chapter is designed to address clinical issues encountered in moving a casualty by air on a UAV. It will not address all issues associated with aeromedical evacuation or CASEVAC, but only those which create a requirement for decisions as to what conditions need to be met to ensure, as far as is reasonably practicable, that it is safe to move that casualty on a UAV. The first tenet of medical care is "do no harm" and while use of a UAV for evacuation will soon be a possibility, these standards must ensure that medical professionals are not put in a position where they inappropriately utilize a UAV for evacuating a casualty and, in doing so, place that casualty at greater risk than can be justified. As discussed previously, Medical Evacuation (MEDEVAC) is the movement of patients under medical supervision (i.e. with the capability to provide care in flight) to Medical Treatment Facilities (MTFs) as an integral part of the treatment continuum. Consequently, MEDEVAC, even on a UAV, is deemed to be within the medical chain of custody during which degradation in the level of care is not acceptable. Therefore, placing a casualty on a UAV without an attendant should only be undertaken where there is a benefit to the casualty and that casualty is not put at additional risk as compared to waiting for alternate evacuation modes. However, Casualty Evacuation (CASEVAC) is the unplanned movement of casualties without in-flight medical support or opportunistic movements by available non-medical or medical personnel. It is anticipated that this may be the most likely scenario in which a casualty is transported by a UAV. In this chapter, we consider the movement of the casualty in 3 situations: movement by a remotely-piloted conventional aircraft, MEDEVAC on a designated UAV and CASEVAC on a UAV. Issues to be considered include: whether the casualty being CASEVAC'd has entered the medical treatment chain and what clinical conditions need to be met to deem it is acceptable to place a casualty in a UAV without a medical attendant. As we are considering movement of casualties by air, the physiological effects of flight on the clinical conditions will be addressed where appropriate. This chapter is intended as a guide rather than firm prescriptive rules, because this process must be a risk assessment made on the ground by medics and commanders together having considered the prevailing environment, the availability of evacuation assets, and the nature or seriousness of the injuries.

### 5.2 OVERARCHING MEDICAL STANDARDS

The schema of care for military trauma casualties is generally based on Advanced Trauma Life Support (ATLS) guidelines<sup>1</sup> with heightened priority on control of bleeding:

- Control of Catastrophic bleeding.
- Control of Airway.
- Ensuring adequate Breathing, i.e. oxygenation.
- Maintaining Circulation to ensure perfusion of tissues.

---

<sup>1</sup> We recognise that ATLS per se is not the actual system which is used in most of our Nations for deployable trauma care, but the systems actually used, such as the US TCCC and the UK BTLS, are all generally based on the principles of ATLS. Therefore we refer to ATLS for convenience.

- Disability – Neurological status.
- Exposure.

The military health services in recent conflicts have transformed the survival of wounded personnel through advanced control of bleeding with tourniquets and initial airway control by care provided by other soldiers (“buddy care”) and by combat medics with training in airway management and haemostatic dressings. The standards of care available can have a permanent effect upon outcome, and the effects of poor quality can rarely be reversed later. Every effort is made to ensure that medical care is based on internationally accepted best medical practice and the transportation of casualties should not create circumstances in which that immediate care is compromised by the conditions under which the casualty is evacuated. In addition, physical restraint of the casualty while unattended will be needed to ensure that aggravation of existing injury or further damage does not occur.

MC 326/3 states that time is a fundamental principle in the effectiveness of medical care. The amount of time which passes between the time of injury and the receipt of appropriate medical intervention will affect the general outcome of medical care, including the risk of death, the speed of recovery, and potentially the level of residual disability. Therefore, best medical practice includes rapid transportation to the correct level of medical care, but it is complicated by the new NATO doctrine in MC 326/3, which states:

*“The initial response at point of injury is crucial. For the most seriously injured, provision of bleeding and airway control must be achieved within 10 minutes of wounding.... It is important that a continuum of care is provided with the necessary treatment and evacuation capabilities available throughout the chain to meet clinical requirements. In this way medical support will save lives, minimise the effect of injury and create the conditions for effective rehabilitation that returns personnel to active military duty.”<sup>2</sup>*

Based on this doctrine, it is desirable and highly likely that injured personnel will have their airway preserved and bleeding controlled prior to a UAV being available to evacuate them. Therefore, the transportation provided has to include the capability to maintain that level of care if it has been already provided.

### **5.3 CATASTROPHIC BLEEDING**

It is reasonable to assume that correctly applied dressings and tourniquets will remain functional during a short flight. Failure to apply them adequately could result in loosening and fatal bleeding. Casualties having non-compressible intracavity bleeding may be controlled with haemostatic agents prior to movement, but due to the very nature of these wounds it is unlikely the presence of an attendant would make significant difference to the outcome. Additionally, IV fluids, if available at the forward location, would be required to support such casualties during transport and these are considered below.

### **5.4 AIRWAY CONTROL**

This is potentially an issue in any casualty injured sufficiently to require such expeditious evacuation. In a casualty breathing spontaneously, a simple oropharyngeal airway will usually remain in place with an oxygen mask applied, if available. However, more advanced airways, such as laryngeal masks or endotracheal tubes would need to be secured and have inflatable cuffs to protect the seal of the airway. But altitude changes

---

<sup>2</sup> MC-326/3, para 3.10.

require these cuffs to be filled with saline to prevent them bursting on ascent as they cannot be adjusted during flight. Additionally, there is a requirement to ensure that the airways are correctly placed, because an attendant can observe signs in respiration that may suggest misplacement and could be in a position to restore the airway, but this would be impossible in unaccompanied mid-flight on a UAV. Securing the airway can be especially difficult when maxillo-facial or neck trauma exists. Of concern, is the danger of aspiration in flight with the casualty placed in the supine position, especially with the difficulty in securing a good airway-cuff seal. Traditionally, basic first aid teaches responders, who are on their own, who have to leave a casualty to raise help, to place the casualty in the “recovery position” on their side. During flight the risk of vomiting is such that the airway could be compromised and, therefore, consideration should be made to placing the casualty on their side for the flight if their condition permits adequate chest movement in this position. This will be addressed again in the restraint discussion. Generally speaking, casualties who have a clinical need for advanced airways should not be candidates for CASEVAC without accompanying personnel on any vehicle, including UAVs.

#### **5.4.1 Breathing**

- A) Clearly, any casualty who requires assisted ventilation either requires an attendant or a mechanical ventilator. It is highly unlikely in the circumstances that a UAV may be considered for CASEVAC that a ventilator would be available. However, if anticipated scenarios include planned MEDEVAC of a patient on a ventilator then the platform will need to be capable of monitoring the ventilator status of the patient and receive feedback automatically or remotely. While modern telemedicine technology could provide a “down-feed” of the patient’s status, “up-feed” to provide control or adjustment of ventilators is not available at the time of this paper<sup>3</sup>.
- B) Supplemental oxygen is a standard and possibly near-universal therapy in emergency medical care. Its use is not only advocated but currently mandated in Advanced Trauma Life Support, and in Pre-hospital Trauma Life Support. However, despite its theoretical advantages in preventing hypoxia and acidosis, its utility has never been proven in the trauma population when delivered in the pre-hospital setting.<sup>4</sup> Nevertheless, even though the benefit may be unproven at sea-level, UAV platforms will be unpressurized and it is highly likely that a safe altitude would direct the use of supplemental oxygen, should it be available. Unlike oxygen use for healthy aircrew, the requirement for a casualty with severe trauma is sufficient oxygen delivered through a venturi style mask, not taking into account any additional requirements for altitude. Patients for whom this level of therapeutic O<sub>2</sub> is necessary are probably not optimal candidates for evacuation by air in CASEVAC mode, and should preferentially be moved via MEDEVAC (Air Ambulance).
- C) In multiple trauma situations, at first assessment in the field or in remote medical outposts without imaging facilities, small pneumothoraces may go unnoticed. Unfortunately, on ascent in the UAV any pneumothorax will expand in volume and increasingly compromise the casualty’s breathing. With accompanying medical attendants, a needle chest decompression can be conducted in flight, but on a UAV evacuation, this may have to be anticipated. Any casualties from blast mechanisms have the possibility of a pneumothorax as do those with blunt trauma to the chest. These casualties should be examined as carefully as circumstances allow for signs of pneumothorax and, where confirmed or when doubt exists, have a needle decompression conducted or a chest tube inserted prior to flight.

---

<sup>3</sup> Telecon with Lt. Col. Eppolito, USAF SG Consultant in Telemedicine 1 August 2011.

<sup>4</sup> Stockinger, Z.T. and McSwain, N.E. Jr. “Prehospital Supplemental Oxygen in Trauma Patients: Its Efficacy and Implications for Military Medical Care.



## **5.5 CIRCULATION**

As initially stated under control of bleeding, hypovolaemic shock is a major cause of death in severe trauma, and control of bleeding needs to be accompanied by volume replacement and, where possible, blood products to maintain the casualty's ability to circulate oxygen and coagulate. Movement in flight can jeopardize the cannula siting, or fluids may need to be replenished. In manned evacuation, monitoring of blood pressure and pulse gives an indication of the effectiveness of the circulatory resuscitation and can prompt the attendant to adjust dressings or fluids in reaction to unfavourable signs. During unmanned flight, remote monitoring would be required for MEDEVAC and the ability to adjust or replenish fluids. These fluids require either vertical separation from the patient or a pump sufficient to provide adequate flow into the patient. It would not be acceptable for a patient requiring fluid replacement under such critical resuscitation situations to have IV fluids unavailable during a period of movement, during which patients often deteriorate without active management.

## **5.6 DISABILITY**

Many casualties with major trauma will have head injuries causing altered consciousness. As discussed above, trauma above the clavicle line can compromise the airway, but patients with a Glasgow Coma Scale (GCS) < 8<sup>5</sup> in a supine position will need to have their airway actively maintained. Where oxygen is available and the expertise exists, intubation and high concentration oxygen is indicated to maintain oxygenation, especially at altitude. Currently, manned MEDEVAC of such patients requires a team of specialised medical personnel, so automation of these monitoring and support functions will require significant advances to reach a level of care needed for MEDEVAC on UAV. Where the expertise has not been available and expeditious evacuation is the priority, decisions will have to be made on whether the patient's airway is sufficiently patent to survive the evacuation and whether the requirement for oxygen precludes flying if exposure to altitudes above 10,000 feet is involved.

## **5.7 EXPOSURE**

Bearing in mind the mechanisms by which heat exchange from the body takes place, it is not surprising that hypothermia is commonly found in victims of major trauma/bleeding and this has significant impact on the effectiveness of the body's blood circulation. Severely injured individuals tend to lose warmth through all the usual mechanisms, even when ambient air temperatures are relatively high. This is compounded by open wounds, hyperventilation (often associated with pain or anxiety.) and by inactivity or unconsciousness. Most notably, body heat production is greatly restrained. Many clinical studies have addressed the issue of hypothermia in major trauma, and a close relationship between core body temperature and mortality has been revealed. Based on these correlations, hypothermia has been identified as an independent risk factor, which, together with coagulation defects and acidosis, constitute "the lethal triad" of trauma. Accordingly, most trauma manuals prescribe immediate and aggressive re-warming to improve outcome. There is a little confusion resulting from clinical investigations which has suggested that hypothermia increases survival in a variety of life-threatening emergencies such as myocardial infarction and traumatic brain injury. Not only is this a highly specialised rapid cooling, the common denominator of these cases is lack of extensive bleeding, and the negative impact of reduced temperature on coagulation. Therefore, since we anticipate the majority of casualties in the military who will require UAV CASEVAC/MEDEVAC will have major trauma with significant blood loss, hypothermia will not only be an issue on the ground but will be compounded by flight if conducted in an aircraft that is not designed for providing adequate environmental temperature control.

---

<sup>5</sup> United Kingdom National Institute of Health and Clinical Excellence Guideline 56 head Injury.

## **5.8 RESTRAINT AND STABILIZATION OF SPINAL INJURIES**

- A) Any casualty being transported on a UAV will require adequate restraint while being transported. Traditionally, casualties are strapped to a stretcher (litter) in the supine position and preferably with the head toward the nose of the aircraft, requiring shoulder straps and ideally a 4 or 5-point harness to protect against acute movements or decelerations. Circumstances and prevailing conditions may only permit straps around the casualty, but some form of secure restraint would be required to help mitigate further injury. When a patient is evacuated with an attendant, the supine position is appropriate because any airway issues can be managed. However, while the casualty is unattended it may be appropriate to place an unconscious casualty in the “recovery position” and a harness may need to be designed to fit a NATO standard stretcher that can accommodate a casualty in this position. This would be a new requirement not previously recognised.
- B) Optimal care for patients with spinal injury includes initial resuscitation, immobilization, extrication, and early transport of the patient to a suitable MTF. To maintain immobilization after this type of injury is suspected requires a spinal board, which is unlikely to be available in the CASEVAC scenario. Moreover, patients with cervical spinal cord injuries (cervical SCI) have a high incidence of airway compromise and pulmonary dysfunction; therefore, respiratory support measures should be available during transport. Several studies suggest that rates of morbidity and mortality of SCI patients decreased after the advent of sophisticated transport systems to appropriate facilities.<sup>6</sup> Therefore, any patient having suspected cervical SCI and deemed to be in the medical evacuation chain requires cervical spinal splinting. In military combat operation where extraction under difficult conditions may require use of a UAV, their clinical condition or the operational environment may not permit time for careful immobilization. Indeed, it is suggested that cervical spine stabilization in penetrating trauma patients delays treatment and only prevents one death from cervical SCI for every 66 patients<sup>7</sup>. This could mean that, where speed of evacuation is paramount, we should not worry about cervical spine injury immobilization when dealing with major trauma, as anticipated in these scenarios. In patients where care and extra time is required to secure their spine and the environment permits, there is time to wait for a conventional manned aircraft with medical attendants.

## **5.9 MEDEVAC IN OPTIONALLY PILOTED AIRCRAFT**

Optionally piloted aircraft are conventional in their load and patient carrying potential. Therefore, these aircraft could potentially be used for either MEDEVAC or CASEVAC under the same conditions as if they were manned. The fact that there is no pilot does not necessarily preclude a medical attendant from accompanying the patient and so all normal contemporary clinical standards and constraints should apply in this scenario.

## **5.10 MEDEVAC IN AIRCRAFT DESIGNATED AS UNMANNED PLATFORMS**

As discussed above, MEDEVAC is part of the medical treatment chain and requires certain standards of care since medical intervention has commenced. Best practices should apply, and accordingly no degradation in the level of care is acceptable during transport. Therefore, based on standards when an attendant is able to accompany the patient and the discussion above, there are minimum standards for the UAV platforms that

---

<sup>6</sup> Hadley, et al. “Transportation of Patients with Acute Traumatic Cervical Spine Injuries”.

<sup>7</sup> Elliott, R. et al. “Spine Immobilization in Penetrating Trauma: More Harm Than Good?”.



would be required to be met for MEDEVAC on a UAV. There are 2 scenarios to consider. In both it must be assumed that MEDEVAC is required to be expeditious due to the local threat environment otherwise manned MEDEVAC would be permissible.

- **Scenario 1:** A patient with mild to moderate trauma who is sufficiently conscious to maintain his/her own airway, but who requires urgent evacuation to a higher level of medical care. The clinical considerations are:
  - Does the risk of degradation of the clinical outcome by waiting for the environment to become more permissive outweigh the risk of exposing the patient to the UAV's anticipated altitude, patient/supply compartment, and risk of further injury should the UAV be under fire or suffer a mishap? This includes having adequate restraint for the patient, bearing in mind the injuries involved. Some injuries will be incompatible with tight straps across painful wounds.
  - Is it possible that the patient has occult trauma that may deteriorate with time (the shorter the flight the less risk this poses) or by exposure to altitude? This will be based on knowing the mechanism of injury and comprehensiveness of primary survey possible prior to flight.
  - Does the level of analgesia required pose a threat to the patient's respiratory performance during flight?
  - Is the patient sufficiently prepared for exposure to the cold?
- **Scenario 2:** A patient who is seriously injured and requires active monitoring of life signs, management of airway, ventilation and cardiovascular system. The clinical requirements, in addition to those mentioned above, include:
  - Systems for monitoring the patient's airway patency and respiration, including ventilator performance if appropriate. Based on that surveillance, an up-feed is required to be able to adjust oxygen or ventilator settings in response to changes in the patient's condition.
  - Systems for monitoring the patient's cardiovascular status which are able to adjust and replenish IV fluids as required, including maintaining fluid temperature.
  - A compartment that has sufficient space for IV fluids, oxygen, a ventilator and a vital functions monitoring system. The compartment needs to be regulated for temperature and should be able to accommodate a spinal board or a stretcher with a harness, including restraint in a supine or "recovery position".

Currently the technology for up-feed control of the patient's management is not sufficiently mature to meet these standards. At the time of publishing this paper, the recommendation is that MEDEVAC for unconscious and some other seriously ill patients on a UAV does not meet clinical standards of care and therefore should not be undertaken. As the technology develops, it will be necessary to review this position and revise the recommendations as appropriate.

## **5.11 CASEVAC ON UAVS**

As described earlier, by definition, a casualty being CASEVAC'd has not yet entered the formal medical chain of care and so different standards of care apply. The casualty is being moved expeditiously to be able to receive appropriate care for saving life, limb or eyesight. This may only be removing them from immediate danger to permit a medical attendant to provide early resuscitative care or, should it be appropriate, to evacuate them opportunistically to a nearby MTF. The UAV utilized for this evacuation will not necessarily

have been built to carry casualties, and certain clinical conditions will clearly compromise the casualty's chance of recovery or even increase the risk to his/her life. Therefore, these are guidelines to enable the personnel calling for the evacuation, and those coordinating the response, to make that risk assessment. If these guidelines are met, and if the UAV meets flight/occupant safety standards as described elsewhere in this document (see Chapter 6), then CASEVAC by UAV is clinically justifiable and may be life-saving.

- Active moderate to severe bleeding must be controlled and appropriate field dressings and tourniquets securely applied prior to flight.
- The casualty must be able to breathe spontaneously and, even though they may benefit from oxygen, be able to survive the journey without supplemental oxygen.
- The casualty should be able to be placed in the recovery position if unconscious.
- There should be an internal compartment or secure external structure for the casualty with sufficient restraint to prevent the casualty falling from the UAV or moving around inside the aircraft (e.g. in case of turbulence) during flight.
- The risk of evacuation by UAV to the life of the casualty for whom CASEVAC is being considered must be less than if they remain at their current location while waiting for MEDEVAC or another platform that can accommodate an escort. It is only in these circumstances that CASEVAC really makes good clinical sense. This is a risk assessment that must be made by the commander on the ground with advice from medics, if available, locally or remotely.

## **5.12 RECOMMENDED NATO UAV FLIGHT SAFETY STANDARDS**

In addition to those clinical decision points discussed above, the RTG has developed a set of aircraft standards which should be met by any UAV being considered for use as a CASEVAC platform. NATO directives must be developed which will give guidance to commanders on this decision-making issue (to be considered after consultation with medical authorities in the theater of operations). The UAV, before being approved for CASEVAC use, should be demonstrated to be capable of operating safely and efficiently under environmental conditions outlined herein or as specified in other UAV requirements documents. An objective performance requirement for UAV casualty movement will be that casualty carriage shall be via internal carriage, in a compartment designed with environmental controls that meet or exceed the "passenger" compartment environment conditions of current manned helicopters used for casualty movement.<sup>8</sup> These standards are discussed more fully in Chapter 6, and a summary of the recommended standards is found in Section 6.1.7.1.

---

<sup>8</sup> Here, we specifically exclude from consideration the lifting of a patient in a cage or stokes litter at the end of an external cable, e.g. from the deck of a ship at sea. This is considered more "extraction" than "evacuation", which is what we are discussing.



## **Chapter 6 – SAFETY AND OTHER OPERATIONAL ISSUES**

### **6.1 INTRODUCTION**

If UAVs are to be considered for CASEVAC use, many issues must be considered beyond the strictly clinical and operational requirements. These issues involve safety, flight characteristics and capabilities, and perhaps more importantly gaining support for such use from the potential user community. In developing our concept, we have considered all those issues, as well as the critical one of ensuring support from the pilot community. We have identified desirable/optimal requirements to allow UAVs to operate in CASEVAC mode – it is clearly recognised that not all logistics UAVs will have these design characteristics, and thus may be less suitable than other similar UAVs for casualty transportation. We are not trying to design a UAV air ambulance, but to identify characteristics which would permit or deny such usage. These are certainly not medical issues, but will play a role in the determination as to which UAVs are suitable for CASEVAC use. Most logistics UAVs which derive from current manned systems will already meet these desiderata, and we must assume that any logistics UAV must meet the majority of them to be a functional addition to the logistics system. Thus, the following criteria must be considered, even though they must be applied/integrated prior to the fielding of the aircraft.

#### **6.1.1 Critical Assumptions**

Given the critical role that manned aeromedical evacuation platforms fulfill, we must make certain assumptions regarding the expected performance that an unmanned platform given the same critical role must fulfill. Additionally, it is assumed that all patient care protocols, continuity of care, moral, legal, and ethical standards are adhered to throughout the evacuation process (see Chapters 3, 5, and 8). We note that most UAVs currently being proposed for the logistics role are derived from certified or certifiable pre-existing platforms. Thus, they already meet many of the specialised criteria found in this chapter. Our intent herein is not to design a new UAV, but to assist the operator in determining whether any particular UAV (of several which may be available) is suitable for CASEVAC use from this viewpoint.

#### **6.1.2 Design Safety**

##### **6.1.2.1 General Requirements**

The concept of “casualty as cargo”, or the carriage of a casualty in an aircraft not specifically designed to carry people, adds multiple requirements to the normal “cargo design requirements”. Essentially, successful adoption of this concept will require the addition of design requirements to ensure casualty safety. We believe that any aircraft to be used for UAS CASEVAC must meet safety, environmental conditioning, and reliability standards of current manned helicopters. Paramount to designing standards for previously unmanned systems to be “manned” with precious human cargo is the concept that all precautions and risk-reducing measures must be installed, and certainly no expense should be spared to ensure that the aerial system is safe for manned flight. Each Nation will have its own certification requirements, but as an example, for a UAV to be U.S. Federal Aviation Administration (FAA) and U.S. Code of Federal Regulations (CFR) Compliant, FAA Order 8130.34 Airworthiness Certification of Unmanned Aircraft Systems, requires that characteristics be engineered into safety design standards such as:

- Weather phenomena performance; for example, the ability to fly with no ceiling, no visibility (“0/0 capability”);

- Ability to anticipate failure modes; for example, software capable of monitoring and reporting aircraft systems status to the operator and to correct for failures as they occur; and
- Robust intelligent software and advanced platform sensors; for example, digital flight control computers and visual and electronic onboard sensors.

#### **6.1.2.2 Crashworthiness**

FAA Order 8130.34 already demands that unmanned systems possess the capabilities noted above to compliment crashworthy design characteristics. The unmanned system conducting CASEVAC should be equipped with high GHZ absorbing landing gear, self-sealing fuel cell(s) and fuel lines, structurally enhanced occupant spaces, and vibration and GHZ absorbing/dampening protective compartments. Building unmanned systems to the same standard to which manned systems are designed will enhance survivability, safety, and reliability.

#### **6.1.2.3 Reliability**

Safe designs should possess redundant aircraft systems such as electrical generators, hydraulic pumps, or fly-by-wire transducers. The craft should incorporate ease of maintenance technologies such as line replaceable units, and Integrated Vehicle Health Monitoring Systems (IVHMS). Designs should be validated as high operational readiness rate and low failure rate systems.

#### **6.1.2.4 Aircraft Performance Capabilities**

It is desirable that a UAV used for CASEVAC purposes be Hover Out of Ground Effect (HOGE) capable in 35 °C or greater environmental temperatures and should be able to operate with appropriate power margins at or above 14,000' MSL. This high, hot, and heavy capability may require dual engine equipped systems that must be One Engine Inoperative (OEI) capable. For the unmanned system to be most effective in this role it should possess a minimum forward airspeed of 120 knots ground speed.

#### **6.1.2.5 Environmental/Weather Safe Design Characteristics**

The system design standard will be required to operate in extreme heat and cold conditions. It must possess tolerance to high winds and be capable of operating in moderate turbulence without causing injury to onboard casualties. The system must not be degraded while operating in zero-visibility or zero ceiling conditions (0/0) such as fog, haze, smoke, sand, dust, snow, or heavy rain. Additionally, it should be able to safely operate in moderate to severe icing conditions, as well as in other difficult environmental conditions, e.g. mountains, ridge lines, pinnacles, confined areas, jungle, and slopes.

#### **6.1.2.6 Handling Qualities and Flight Control Laws**

Inherent to the design of the system, the handling qualities and flight control responsiveness must not create undue G force acceleration, vibration, roll-rate, or other forces such that they would cause more harm to the casualty.

#### **6.1.2.7 Intuition and Decision Making**

Intelligent software must be able to replicate immediate instinctive-type responses given constant variable changes while operating within the fluid battlefield environment. The unmanned system will have to react to the en route mission redirect, mission aborts or alternative landing zone selection. It will have to negotiate the

management of unexpected events such as; systems malfunction, hostile fire, unexpected hazardous terrain or weather, or other en route mission changes. Responses to these types of events could be managed fully autonomously, via remotely piloted technologies, or through electronic tethering to a human in the loop.

### **6.1.3 Navigational Design Capability**

For a completely autonomous system design to operate safely, high fidelity navigation systems will be required to achieve the fineness required to conduct confined area, pinnacle, rooftop, or helipad approach and landings. Remotely Piloted Vehicles (RPVs) will require robust sensors if the pilot is to possess the necessary visibility and situational awareness required to safely land the craft. (More information on sensors is located in Sections 2.2.5.7 and 6.1.5). Modern-day navigation systems are subject to interference, spoofing from enemy systems, unreliability, and even failures. Autonomous unmanned systems will require the fidelity of better than one meter accuracy for landing, therefore, the latest navigation signal protection technologies will be necessary. Design standards should not suffer from the increased weight of these systems and suffer loss of architectural design space to house these potentially heavy-large navigation boxes. Additionally, navigation flight computers must be redundant (likely two independent flight computers), redundantly powered (separate AC or backup DC power sources), and all should be shielded from Electro-Magnetic Interference (EMI).

#### **6.1.3.1 State of the Technology – Global Positioning Systems (GPS)**

GPS is the current industry navigation system in use throughout the aviation community. Accuracy to within a few meters is achievable given ample amount of signal strength received from orbiting satellites. Signal coverage can be inconsistent depending upon the time of day, terrain-location, and fluctuations in atmospheric conditions. The GPS signal can be spoofed by the enemy through interference, false signals, or signal blackout. Therefore, GPS systems must possess protections through encryption hardware/software if they are to safely conduct CASEVAC or any other critical missions.

#### **6.1.3.2 Embedded-GPS and Blended Inertial Navigation Systems (INS) Systems (Abbreviated as EGI)**

These systems provide integrated navigation solutions for systems which are equipped with a MIL-STD 1553 digital data bus, for example. An EGI system has embedded GPS receivers into ring laser gyro inertial navigation systems. Some systems are light-weight, weighing less than 18.0 pounds. These are reliable navigation systems, some versions having a mean time between failures guaranteed by the manufacturer to be at least 6,500 hours. The EGI will provide extremely precise location to the aircraft navigation computer. The EGI is the current digitized GPS solution for most modern helicopters. EGIs utilize combined source navigation signal solutions to produce the best navigation fidelity. The potential downside of these systems is that they can take several minutes (average 4 – 6 minutes) to “align” therefore utilizing this type of navigation system for a fully autonomous unmanned platforms as part of a time-critical launch in response to an urgent CASEVAC request, could result in the loss of precious response minutes before reaching the casualty, unlike in a manned a/c in which the pilot can fly the aircraft during the alignment process.

### **6.1.4 Unmanned Aircraft Survivability in Hostile/High Threat Areas**

Aircraft survivability equipment such as chaff, flares, laser detection, flash detection, infrared defence capability, and other system design protective features will enhance safety and mission success for an unmanned system operating in hostile fire zones. These protective systems can add to gross weight of the unmanned systems, reduce their aerodynamic properties, and decrease available power as a penalty of these

additive factors. The future unmanned system operating in the modern battlefield environment conducting life-saving CASEVAC will have to be designed to accommodate these protective factors into the system safety and survivability specifications.

### **6.1.5 Complete Autonomy, Remotely Piloted Vehicles (RPV), Human In The Loop (HITL) Systems and Sensors**

Complete autonomy of unmanned systems conducting CASEVAC will require robust-reliable navigation and flight control computers. Autonomous unmanned systems will require highly sophisticated mapping technology and decision making software that must be able to assess the suitability of the Landing Zone (LZ) including the identification of ground hazards, wires, poles, ground personnel, ground vehicles, or even livestock that may have wandered into the landing area. Human-In-The-loop (HITL) technology could mean providing a man-machine electronic link to visual sensors to make final approach assessments regarding LZ suitability. HITL may include a Remotely Piloted Vehicle (RPV) capability where the pilot takes control of the landing sequence while viewing the LZ through on board visual and/or electronic sensors.

#### **6.1.5.1 Visual Sensors**

Forward Looking Infrared (FLIR), various day/night/NVG cameras, and/or Light Detection and Ranging, (LIDAR/LADAR) systems could enhance pilot situational awareness during flight and during the landing and take-off sequence. LIDAR is an optical remote sensing technology that can measure the distance to, or other properties of, a target by illuminating the target with light and often by using pulses from a laser. The system has applications as in Airborne Laser Swath Mapping (ALSM), laser altimetry and LIDAR Contour Mapping. LIDAR has been identified by NASA as a key technology for enabling autonomous precision safe landing of future robotic and crewed lunar landing vehicles. The acronym LADAR (Laser Detection and Ranging) is often used in military contexts. The term “laser radar” is sometimes used even though LIDAR does not employ microwaves or radio waves and is not therefore technically radar even though both systems employ electromagnetic radiation. Trade-offs utilizing designs that incorporate this technology are cost (potentially expensive) and increased weight of the unmanned system. Other HITL/RPV combination options may include the receiving medical unit possessing the correct unmanned system remote control to allow them to assume authority over the unmanned system during the approach to landing phase, taking control and safely landing the craft. This option would, however, require the assignment of trained UV pilots at the medical units, which may not be feasible.

#### **6.1.5.2 Airspace Coordination and Integration into the Battle and National Airspace of an Unmanned CASEVAC System**

Integrating unmanned systems conducting such high priority missions as CASEVAC will require special handling and considerations by airspace command and control authorities. Consideration should be given to establishing pre-planned ingress/egress routes to casualty collection points and medical units versus directing the unmanned system to the point of injury. Pre-planned safe routes will permit traffic de-confliction, as well as safety from terrain and obstacles and enemy/threat locations. Critical to the unmanned system in flight is the ability of the craft to be operated in and around other traffic operating in the vicinity. Control measures that could mitigate potential mid-air collisions with other airborne systems will be critical to airspace safety. US Code, 14 CFR 91.113b states “*vigilance must be maintained by each person operating an aircraft so as to see and avoid other aircraft*”. This will require that the unmanned system possess sensors to see and avoid either visually or electronically. Traffic Collision Avoidance Systems (TCAS) equipment can alert systems operators of unexpected traffic in the vicinity of the CASEVAC operation but would then require either



autonomously responsive technology or an RPV/HITL technology solution intervention to prevent the collision. Further pilot duties are outlined in 14 CFR 91.3a stating *“the pilot in command of an aircraft is directly responsible for, and is the final authority as to, the operation of the aircraft”*. Since the unmanned system may be operating completely autonomously it may not have a “Pilot-in-Command”. Clearly to comply, base-operated, command-directed launch of unmanned CASEVAC systems will imply command and control responsibilities belonging to the originating organization. The availability of necessary frequencies that command a RPV system may be difficult in the electronically saturated battlespace. Frequency band concerns must be addressed through band-width assignments, frequency de-confliction and prioritization. An example of such congestion is: Satellite Communications (SATCOM) bands are not only used to airborne command and control of unmanned systems, but for communications as well, further confounding the issue. Therefore, safe design standards for unmanned CASEVAC systems must have protected airborne command and control linkage and/or dedicated frequency bands if being controlled while acting as a RPV.

### **6.1.6 The Socialization of the Concept**

Socialization of a sensitive and emotion-evoking concept such as utilizing an unmanned aerial system to conduct CASEVAC raises appropriate concerns from the Air Ambulance (MEDEVAC) community at large. Specifically, MEDEVAC Commanders whose time-honored mission (which spans nearly a century and dozens of conflicts), are in particular very passionate about the safety of conducting this life-saving mission with unmanned aircraft. Initial reactions from the U.S. Army MEDEVAC professionals are filled with concern, skepticism, and in some cases absolute horror. Even when the critical assumptions are satisfied (all legal, moral, ethical, operational, and continuity of care factors met) MEDEVAC pilots exploit the “unknown fears” regarding unmanned CASEVAC with great regularity. Quite appropriately, their concerns surround having an unmanned robotic system conduct a mission which they would otherwise lay their lives down to perform. We recognize completely that these are honestly-held concerns, aimed at protecting the casualty, and are not simply Luddite opposition intended to maintain the status quo. Although the RTG believes that these concerns can in fact be met, we have no illusions that doing so will be rapid or easy. This whole concept is going to have to be an evolutionary development, as discussed below. These voiced concerns have been addressed through the safe-ride standards addressed in this document, yet others remain.

#### **6.1.6.1 Relinquishing the Role**

Issues of continuity of care, moral, legal, ethical, and abandonment standards will be thoroughly addressed in other portions of this report (see Chapters 5, 8, and 9, and Annexes C and D). We note that the community of professionals conducting this mission is well aware of the risks and rewards and will likely never relinquish such a noble and successful mission without absolute satisfaction of each design concern.

#### **6.1.6.2 Replacing the MEDEVAC Pilot**

At this time and with the current state of the art, it is simply impossible to replicate the intricacies of the human role played during this dynamic mission. Years of experience, flight aptitude, intuition, instinct, courage, and bravado cannot be installed in an onboard computer and sent out to go collect the wounded. To this community of professionals the mission literally defines their warrior ethos, their passion, and their careers.

#### **6.1.6.3 Evolution of Unmanned CASEVAC CONOPS**

Supplementing or augmenting the MEDEVAC Commander’s mission through unmanned aerial resupply missions may be an appropriate initial integration of such technologies. Socialization of the “trust factor” will

likely begin when multiple successful Class 8 (Medical) resupply missions are regularly conducted without incident.

#### **6.1.6.4 Contingency Missions (The Worst Case Scenario)**

Conditions in which the launch of manned MEDEVAC aircraft is not possible may provide the opportunity for the successful employment of the unmanned system in the CASEVAC mission. Examples of these circumstances may be: 0/0 (hazardous) weather, non-availability of manned CASEVAC/MEDEVAC assets, inhospitable environments such as following a chemical, nuclear, biological, radiological, or explosive attack; or extremely hostile threat environments in which the risk of evacuation would unduly jeopardize aircrew lives. Unmanned vehicles could augment manned evacuation assets during mass casualty situations where the availability of dedicated assets is strained.

#### **6.1.6.5 Routine Mission Support**

After the proven utilization of unmanned CASEVAC platforms during contingency operations, routine patient movement missions may follow. Employment of the technologies would be simplified if operations from prepared surfaces such as helipads to prepared casualty collection points are first achieved consistently and safely. More aggressive applications of unmanned evacuation assets into unimproved terrain, urban environments, confined or hostile areas, or even to the point of injury, could evolve provided the technology safety design is proven reliable, beneficial, and comprehensively sound in every regard.

#### **6.1.7 Technological Safe-Ride Standards for Unmanned CASEVAC – A Summary**

In summary, we propose the following technical (as versus clinical) approach to the challenges for the safety design and functional capability of unmanned systems to be used for CASEVAC:

- Decision making, intuitive software, and/or intelligent design characteristics must exist;
- Hostile fire survivability protections should be fully incorporated into design standards;
- Robust analytical programming with the ability to manage unexpected events and contingencies, aborted landing, mission re-designation en route, and the ability to anticipate failure modes and manage emergency procedures must be incorporated into the design;
- Handling qualities and flight control laws should be designed for patient tolerance to GHz, acceleration, vibration, and safety;
- System power performance characteristics must be high, hot, and heavy capable with safe power margins remaining (allowing operations in environmental extremes);
- Continuity of en route care – provide the highest possible care during all modes of flight (this would apply only to future MEDEVAC use, and will not apply to CASEVAC use);
- There must be capability for navigation through crowded airspace and “See and Avoid” capable, traffic (TCAS) and terrain avoidance prevention software. Fully-autonomous precision approach, hover, and landing capability must be incorporated into the design; and
- The UAV must be fully compliant with all relevant regulatory aircraft design standards and military standards.

### 6.1.7.1 Safety Parameters for Consideration

The table below summarizes a variety of safety parameters which should be considered in selecting a UAV for casualty evacuation use. The standards are those which ideally should be met for use of the UAV in CASEVAC mode, though not all may be available in any given situation. More demanding criteria must be developed in the future event that a UAV is being chosen for use as a dedicated MEDEVAC aircraft. These safety parameters must also be supported by further research (as discussed further in Chapter 7).

**Table 6-1: Safety Criteria for NATO UAS CASEVAC.**

Medical/Safety/Human Factors Criteria	Standards
Inherently Safe	The UAV should be inherently safe or designed to mitigate risk to a casualty (e.g. no exposed sharp edges, no exposed high temperature surfaces).
Safety Rating	NATO or national Air Regulations.
Air Quality	Air quality in compartment must be in accord with usual aviation standards – no exhaust contamination, etc.
Noise/Acoustic Levels	The UAV should be designed to not exceed the 8-hour time weighted occupational exposure limit of 85 dBA within the “passenger compartment”. Noise levels above 115 dBA should not be exceeded for any duration without hearing protection.
Vibration Levels	Should not exceed current UH-60 vibration levels.
Acceleration	< 0.25 G/sec G-onset rate. < 2 Gs in any axis at any time when carrying a casualty.
Flight Control	Remotely Piloted (autonomous take-off and landing).
Interior Configuration	Sufficient space for the casualty lying on folding stretcher or NATO litter without comfort mattress or vibration mitigation technology.
Interior Environmental Temperature Control	Passive Measures (e.g. warming/cooling blankets for casualty).
Immobilisation	A minimum of three (chest, hip, and knee) litter straps or other patient retention devices per stretcher or litter to prevent longitudinal or transverse dislodgment of the casualty during UAS transit.  Some system must be available to firmly attach the litter to the aircraft, to preclude movement of the casualty within the “passenger” compartment during flight.
Egress	Provide the capability with a mechanism for unassisted casualty emergency egress.
Number of Casualties	1.
Oxygen	If available at casualty point of origin and needed in flight, portable patient O <sub>2</sub> must be able to be secured in the “passenger” compartment.

## SAFETY AND OTHER OPERATIONAL ISSUES

Medical/Safety/Human Factors Criteria	Standards
Lighting	Adequate lighting for observation and to preclude patient perception of being stuffed into a “cold, dark box”.
Fluid Containment	Body or treatment fluids should be easily contained within the “passenger” compartment which should be able to be easily cleaned and disinfected after use if exposed to fluids (e.g. disposable absorbent blankets/mats or disposable litters).
Communication	Communication between the UAS controller and the medical coordinator on the ground is desirable.
Usable Payload Weight	> 500 lb.
<b>Operational Issues</b>	
Operational Altitude <sup>1</sup>	≤ 10,000 ft MSL.
Mission Completion Time <sup>2</sup>	60 min.
Flight Control	Remotely Piloted (autonomous take-off and landing).

<sup>1</sup> Oxygen required above 10,000 ft Mean Sea Level (MSL).

<sup>2</sup> Chances of survival for the critically injured depend on immediate surgical care. Delivering a casualty to adequate surgical care as rapidly as possible is the goal.

### 6.1.8 Technology Today and for the Future

- If all these operational/technical requirements can be met, we feel that from a technological point of view, it is quite possible to effectively and safely use UAVs for CASEVAC operations.
- Many UAVs which will likely be able to meet our criteria are currently under development. Some of those currently being developed have been discussed in Chapter 2.

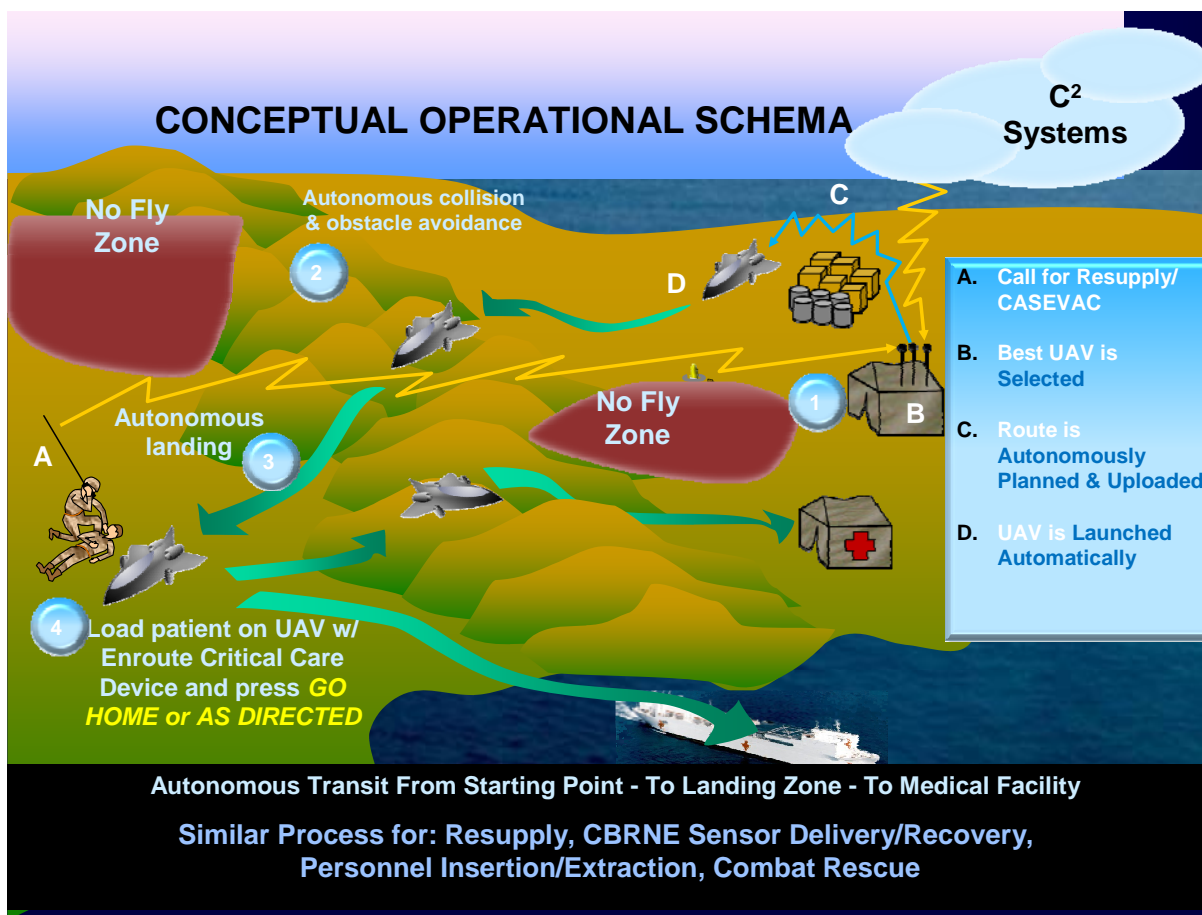


Figure 6-1: A Proposed Operational Schema for UAV CASEVAC.



## **Chapter 7 – EN ROUTE CARE MEDICAL RESEARCH, DEVELOPMENT, TEST AND EVALUATION (RDT&E) GAPS AND STATUS**

### **7.1 BACKGROUND**

The goal of Medical RDT&E efforts is to develop a seamless patient movement system which is integrated with the joint casualty management system, consisting of both non-standard platforms and designated patient movement assets that are capable of effectively and expeditiously transporting casualties and providing maximum en route care from point of injury to final disposition.

Unmanned Aerial Vehicles (UAVs) are considered non-standard platforms that because of their success in recent deployments to combat areas are thought to potentially play a future increasing role in emergency evacuation of the injured soldier. It is critically important to understand that the patient movement environment, be it via surface vehicle such as ambulance, rail, waterborne vessel, amphibious vehicle, submarine, ship or air via rotary or fixed-wing aircraft, poses unique challenges for patient care, mission equipment and medical personnel. Based on the current operational environment of the manned response, major focus areas for the en-route care research are: patient stabilization, patient preparation for movement, patient staging, impacts of the in-transit environment on patient physiology and medical crew/attendant performance, occupational concerns for medical staff, human factors and patient safety, medical personnel training and equipment, environmental health issues, infectious disease and cabin infection control, burn and pain management, resuscitation, life saving interventions, nutrition, alternative medicine, and a wide variety of organ system effects (neurologic, psychological, orthopedic, pulmonary, cardiovascular, gastrointestinal, renal, respiratory). Without a doubt, the effects of the environment on the patient's medical condition and treatment interventions is a singularly distinct issue that must be researched and understood in order to improve patient outcome, and more importantly, prevent a negative outcome. One issue which is frequently ignored, and which in our opinion must be considered, is that of biodynamic evaluations of the impact of new aircraft. The results of such studies should be incorporated into airframe design at the earliest possible time in the development cycle. As regards casualty-carrying UAVs, this is not a major issue at the present, since most UAVs suitable for this role are derived from pre-existing aircraft, but as totally new airframe designs are developed, this issue must not be ignored.

Environmental considerations for a patient compartment in a UAV should include: noise, vibration, turbulence, G-acceleration, temperature, humidity, altitude, electromagnetic interference, and air quality. It is optimum if these considerations can be taken into account during the design phase of the UAV, but if this has not been done, they must be evaluated by the user community prior to the use of these aircraft for CASEVAC. Other considerations for casualty care should include (but not limited to): auxiliary power for equipment, oxygen delivery, suction, closed-loop medical systems, infectious control, litter mounting systems to include immobilization, psychological effects of confined spaces, communications, and data connectivity. Not all of these considerations are directly relevant to CASEVAC use, though all must be taken into account in any possible future efforts to use UAVs in the MEDEVAC role.

### **7.2 RESEARCH GAPS**

The major knowledge gap areas related to casualty transport (to include UAVs) include, but are not limited to:

- Casualty stabilization;



- Casualty preparation for movement;
- Impacts of in-flight/in-transit environment on patient physiology;
- Human factors and patient safety;
- Environmental health issues;
- Infectious disease, and cabin infection control;
- Burn and pain management; and
- Resuscitation.

A critical issue which must be addressed is the lack of a viable forum within the NATO environment in which to discuss (and hopefully in the future to coordinate) such research programs.

### **7.3 RESEARCH SCOPE**

The scope of needed research can be categorized as clinical investigative research, medical technology research and development, and operational research. The scope of such research is applicable to both standard and non-standard transport vehicles.

- **Clinical Investigation Research:** Evaluate in controlled groups the efficacy, safety of novel medical technologies or clinical protocols contributing to improved outcomes of patients transported by UAV. Tasks may span the translational continuum to include early translation into Phase I/II trials, late translation into Phase III/IV trials and regulatory approval, health services research, dissemination to providers and communities, and adoption by providers, patients and the public.
- **Medical Technology Research and Development:** Research, development, and operational testing of novel devices, systems, and other medical products related to use of UAVs, such as future patient transport pods<sup>1</sup>.
- **Operational Research:** Modeling, simulation, research, and analysis of clinical or operational procedures and processes related to environmental and occupational stressors, team performance, training effectiveness, or diagnosis of clinical health problems of concern to beneficiaries of military healthcare and expeditionary operations.

#### **7.3.1 Description of Casualty Movement Environment and Functional Limitations**

The casualty movement environment, be it via surface vehicle such as ambulance or rail, via high speed waterborne vessel, or ship, or in the air via conventional rotary or fixed-wing aircraft or UAVs poses unique challenges for patient care.

- Mission equipment noise levels on some transport platforms interfere with voice recognition and obscure audible physiological and technological signals.
- Vibration can exacerbate and worsen the casualty's medical condition and can damage medical equipment or impair its stability and accuracy.

---

<sup>1</sup> Note that this RTG has not attempted to discuss in detail the development or creation of actual patient cabins, or "patient pods", as currently being developed by the US DARPA. We have attempted to identify requirements and conditions for use, but have avoided actual development or design work, as being outside our scope. The possible future existence of such pods does not affect our evaluation of the potential use of UAVs in CASEVAC in the short-to-medium term, though it may affect future use in MEDEVAC in the longer term.

- Turbulence subjects the entire casualty care environment to unpredictable G-forces, and requires mechanical systems to provide optimum security and methods of securing casualties to ensure they are immobilized to mitigate against negative physiological effects.
- Environmental temperatures are not always well regulated as aircraft altitude changes, and can vary by more than 40°F between deck level and a height of 60 inches above the deck, creating challenges for care of casualties susceptible to shock or suffering from circulatory problems.
- The same is true of ambient air effects on vehicles lacking environmental temperature control mechanisms such as rotary wing or field ground ambulances.
- The relative humidity of fixed-wing cabin air is typically low, which may increase breathing difficulty for some patients.
- Usually, fixed-wing air evacuation missions fly at an altitude low enough to maintain cabin pressures at 8000 feet or less; however, this is not always possible, and medical equipment (e.g. ventilators) as well as fluid connections (intravenous solutions, thoracic drainage, etc.) must be able to withstand violent cabin depressurization without injuring patients.
- Rotary wing aircraft (manned and unmanned) and ground ambulances may operate above 8,000 feet altitude, exposing patients to negative altitude effects that could worsen their physiological state.
- Acceleration effects, mostly on take-off and landing, may influence patient management and patient condition.
- The electromagnetic environment in transport vehicles is unique; mission equipment must be designed and configured to avoid radiated or conducted electromagnetic interference with aircraft, ship and ground vehicle electronics, and must prevent medical equipment malfunctions resulting from electromagnetic emissions by the aircraft, ship or ground radars and transmitters.
- Electrical power outlets and distribution systems adequate for support of required patient equipment vary by transport vehicle and may not adapt to the power requirements of medical equipment, without pre-mission planning and preparation.
- On-board oxygen capacity to support casualty therapy is not always available on transport vehicles, which drives the development and use of light-weight and highly capable carry-on systems.
- The duration of transport can significantly affect both physiology and treatment of the casualty; inter-theater airlift or sea missions are typically long, resulting in extended exposure to the transport environment and requiring extended critical care capabilities.
- The constantly-developing suite of multiple critical care medical devices needed for patient care is heavy and not necessarily integrated or interoperable, which requires intensive monitoring by medical staff and continuously challenges their situational awareness and decision making.

### **7.3.2 En Route Care Research**

En route care research needs to focus on the delivery of in-flight care (if any) which is needed to support casualty movement requirements. Improving this capability will depend on enhancements in:

- 1) Portable medical equipment;
- 2) Adaptation of clinical capabilities for employment on any available and appropriate AE transportation platform;

- 3) Patient management and regulating systems; and
- 4) Clinical and operational training.

As described earlier, characteristics of the movement environment affect human physiology, and more understanding is needed of these effects on patients with comprised physiological systems. The above research areas are applicable not only to manned medical transport vehicles but also to UAVs.

One of the original tasks of this RTG was to review the clinical knowledge to develop recommendations for evacuation, based on specific clinical conditions and the stresses of flight. Unfortunately, we have found that there is very limited evidence-based data available for such evaluation – This subject has simply never been examined adequately. There is a general assumption among those with experience in aeromedical evacuation that in the absence of severe stress (e.g. vibration, acceleration, hypoxia) air evacuation does not pose any significant effects on the patient. However, this has not been adequately demonstrated in any evidence-based way. When additional research on the clinical effects of aeromedical evacuation is proposed, the response is often “But we already know all that!” Unfortunately, that assumption is fallacious. Although the U.S. Army pioneered large-scale helicopter evacuation during the Vietnam era and has evacuated tens of thousands of patients in the current conflicts over the past decade, meaningful research examining rotary wing evacuation in the combat setting is generally lacking. The fact that most casualties with any given condition survive their evacuation (and have a higher survival rate than patients who are not evacuated, for many reasons) does not imply that they are not in fact harmed in any way by the evacuation. We simply have no data which proves that the stresses of rotary wing evacuation do not cause deterioration of patient conditions, even though the vast majority of patients survive their flights. Rotary wing evacuation has ample clinical, technological, and operational areas needing study, yet several significant structural and even “cultural” challenges exist that hinder meaningful research into this area. Thorough understanding of the interactions of environmental extreme conditions and patient aeromedical care onboard current medical transport vehicles is necessary to provide baseline knowledge for possible future transport vehicles such as UAVs, whether in the CASEVAC or the MEDEVAC mode. The evidence-based data generated by studies of evacuations carried out on current aerial platforms can be applicable to and can be extrapolated to UAVs. One example of an area which needs evidence-based research is the clinical management (pre-transport) and transport of patients with head and spine injuries, which will be discussed in detail below. The current standard of care is based on WWII through Vietnam era practices which may or may not produce an optimal medical outcome. A research program is needed to address the patient health hazards associated with vehicle vibration and repeated shock which is believed by some researchers to have unintended consequences for a large population of wounded soldiers.

### **7.3.2.1 Safe Clinical Management and Transport of Patients with Head and Spine Injuries**

In the largest epidemiological study documenting Spinal Cord Injury (SCI) during OIF, it was reported that 7.4% of all casualties sustained combat-related spine injuries<sup>2</sup>. The current civilian and military standard of care for managing suspected head, neck and/or back injury is to apply a cervical collar and transport the patient via backboard fastened to a litter. Very little scientific evidence or data exists to support this method as the standard of care, but rather it has become the long-established practice as part of the evolution of pre-hospital trauma care.<sup>3,4</sup> Up to 25% of SCI occurs after the point and time of injury, either during transit or

---

<sup>2</sup> Schoenfeld, A.J., Goodman, G.P. and Belmont, Jr., P.J. “Characterization of combat-related spinal injuries sustained by a US Army Brigade Combat Team during Operation Iraqi Freedom”.

<sup>3</sup> Ben-Galim, P., Dreiangel, N., Mattox, K.L., Reitman, C.A., Kalantar, S.B. and Hipp, J.A. “Extrication Collars Can Result in Abnormal Separation Between Vertebrae in the Presence of a Dissociative Injury”.

<sup>4</sup> Kwan, I., Bunn, F. and Roberts, I. Spinal immobilization for trauma patients (review).

pre-transport clinical management with many having poor outcomes<sup>5,6</sup>. Approximately one in five spinal column injuries occur with multiple non-continuous segments, thus necessitating a complete spinal column care assessment and management in the pre-hospital setting. Further, in the area of safe pre-hospital management of spinal trauma patients, the question of whether the current generation and practice of use of rigid cervical collars has come under serious question – little evidence-based data exists to support the practice, although this too evolved over time<sup>7</sup>. Haut et al. in a retrospective analysis of penetrating trauma patients<sup>8</sup> found that the 4.3% of patients (n = 1,947) who underwent spine immobilization had a mortality rate twice as much as non-immobilized patients. They concluded that pre-hospital spine immobilization should not be routinely used in every patient with penetrating trauma. To mitigate shock and vibration exposure, a patient's exposure limits to whole body vibration need to be defined. There is no data available on vibration exposure criteria for patients, and this too may be another major area of risk to injured patients and injured tissue susceptible to increased inflammatory processes and cascades<sup>9</sup>.

Problems which need to be addressed, solely with regards to this aspect of evacuation, include:

- Vibration and shock exposure criteria for supine patients with head and spine injuries are unknown. Furthermore, no current vibration mitigation technology, as an interim solution, is available.
- Very little evidenced-based data exists on proper spinal immobilization and transport.
- Very little evidence-based data exists on cervical collar use in patients with spinal injuries.

What is needed is a vibration mitigation strategy along with improvements in the additional identified areas of evidentiary weakness in care – namely, cervical collars and immobilization devices. By solving all three areas, the knowledge and techniques gained will be implemented into safe clinical management and transport of patients with head and/or spine injuries. The purpose of the research is to prevent exacerbation of existing injuries of patients during en route care and validate standard of care to improve patient outcomes.

The research plan should utilize vibration and patient movement Subject-Matter Experts (SMEs) with research collaborations among the military, academic, and industry partners, from all our Nations. The goal is to identify the vibration and shock exposure criteria for supine patients and improve clinical management and transport of patients with head and spine injuries. To get this issue moving forward, an RTO Activity focused solely on this issue would be of great benefit.

Future work should investigate the biodynamic response of healthy supine humans with and without immobilization under simulated vehicle shock and vibration. Animal models with head and spine injuries due to blunt and/or blast impacts should be considered. Additionally, the use of cadaver models under shock and vibration exposure should be considered. The complete work would produce acceptable industry standards defining mechanical shock and vibration exposure criteria for transporting patients as well as determining appropriate standards of care.

---

<sup>5</sup> Hadley, M.N. Cervical Spine Immobilization before Admission to the Hospital.

<sup>6</sup> Hadley, M.N. Transportation of Patients with Acute Traumatic Cervical Spine Injuries.

<sup>7</sup> Kwan, I., Bunn, F. and Roberts, I. Spinal immobilization for trauma patients (review).

<sup>8</sup> Haut, E.R., Kalish, B.T., Efron, D.T., Haider, A.H., Stevens, K.A., Kieninger, A.N., Cornwell, E.E. and Chang, D.C. "Spine Immobilization in Penetrating Trauma: More Harm Than Good".

<sup>9</sup> Hadley, M.N. "Transportation of Patients with Acute Traumatic Cervical Spine Injuries".

Over the years, The ISO 2631 standard has addressed human exposure to whole body vibration of the healthy individual in both seated and standing positions. But the committee is currently interested in pursuing vibration standards for the supine, and in particular the injured, human. This is an important step in the future design of UAV transport pods for casualties, and would provide design and safe standards for the material developers. The U.S. Army Aeromedical Research Laboratory (USAARL) is currently pursuing multiple research and development initiatives to address this critical problem and has partnered with a number of military, academic, and commercial organizations in identifying vibration exposure limits as well as finding vibration mitigation solutions.

The goal is to produce meaningful evidence-based data that can be used by NATO, the national military services, civilian, and scientific communities to improve casualty evacuation, resulting in lessened morbidity and mortality. This information is critical to the design of all future casualty transport systems and vehicles.

### **7.3.3 Medical Carry-On Equipment Test and Evaluation**

#### **7.3.3.1 Background**

Several Nations have developed systems for testing of medical equipment. As one example, the following is the process used by the United States, which is similar to, though more comprehensive than, that of other Nations. The first United States tri-service meeting on carry-on medical equipment test and evaluation was held at the U.S. Army Aeromedical Research Laboratory (USAARL) in February 2001. The outcome of that meeting was the development of the United States' Joint Airworthiness Certification (JAC) requirements. The JAC requirements document was an overwhelming success story which quickly led to expediting joint certification, lowering testing costs across the services, and building a stronger collaboration between the U.S. Army and U.S. Air Force test laboratories (namely ACE/USAARL and the Aeromedical Test Laboratory (ATL) located at Wright-Patterson AFB). Patient en route care may occur during all transport, whether using air, land, or sea modalities. There is a strong possibility for the same piece of equipment to be exposed to all of these environments within one transport cycle. Therefore, there is a recognised need to expand the current JAC document to address land and sea medical transport environments. The USAARL hosted the second United States tri-service meeting on carry-on medical equipment T&E in May 2007. Action items from the meeting were aimed at amending the JAC requirements to better reflect current operations as well as to include land and sea test requirements such as sand, dust, salt fog, and ground vehicle vibration.

#### **7.3.3.2 Test Standardization**

There are several test standards for medical equipment used by various NATO Nations. Harmonizing these standards is critical for successful interoperability and equipment use throughout the Alliance. It should be noted that all test standards, in general, address somewhat similar electromagnetic and environmental extremes. Test standards describe, in detail, the test procedures for medical equipment that will be used onboard military transport vehicles during en route patient care. In general, the standards include a baseline performance assessment, laboratory tests, and an in-flight assessment. The baseline performance assessment verifies that the test article operates in accordance with the manufacturer's specifications. The two main goals of laboratory testing are to identify the potential safety concerns that the test article may pose for the aircraft, patient, and crew and to also identify the physical or functional degradation that the test article may experience within the operational environment. Laboratory tests include but are not limited to vibration for air and ground vehicles, electromagnetic interference, climatic, altitude, rapid decompression, explosive atmosphere, acceleration/crash, blowing dust, blowing sand, and blowing rain. After completion of laboratory testing, the test article is evaluated for "fit, form, and function" as well as EMC compatibility with the aircraft

during actual aircraft flights by test personnel, medical personnel, and qualified medical flight crew to validate laboratory findings and assess human factors. The lack of a standard NATO system for ensuring such analyses is a critical defect. Therefore, it would appear useful to discuss this issue within the NATO Aeromedical community, with the objective of gaining agreement to standardizing these processes as an Allied Medical Publication.

#### **7.3.3.3 Knowledge Gaps**

- A) Undoubtedly, airworthiness testing and certification has improved over the years in most NATO Nations to include clearance to use state-of-the-art medical technologies aboard various fixed-wing and rotary-wing medical transport aircraft. However, challenges still exist within the testing community. In general, existing certified medical products are constantly modified by the manufacturers due to technological advancements and/or changes in sub-component supply sources. These modifications often compromise airworthiness and as such, require re-testing. Although USAARL and the ATL have a process in place to address “configuration management”, it is up to the manufacturers to notify the military when the changes to the medical device have been made. It is highly suspected that this notification does not always occur.
- B) Current testing requirements in test standards for carry-on medical equipment are tailored from military standards which are intended for installed equipment aboard the aircraft. Specifically, there is a knowledge gap regarding the operational vibration and shock signatures for carry-on medical equipment across the spectrum of en route care vehicles. The current vibration signatures in the military standard do not represent the operational and lifetime vibration environment for such carry-on medical equipment (the predominate technology for use in a UAV transport platform) The signatures need to be revised due to the shorter life cycle, limited usage, and location of carry-on medical equipment on-board en route care vehicles.
- C) Feedback from the field regarding the performance of medical carry-on devices is mostly anecdotal and lacking detailed documentation. Medical equipment surveillance and trending of failures (if any) has been identified as an existing knowledge gap that is important to the testing community. For example, the exposure of medical equipment to extreme environmental conditions such as high temperatures and blowing dust can cause significant decrements in the operational performance of the equipment.
- D) Night Vision Goggle (NVG) testing is critical to the safety of and protection for both military crew members and casualties. Nations currently assess the blooming effects of medical carry-on devices in laboratory settings; however, NVG criteria for medical devices located in the cabin area of helicopters remain undefined. This knowledge gap should address whether medical devices in a tactical environment must be NVG compatible or NVG friendly. The testing laboratories of the various Nations recognize the need to characterize how carry-on medical equipment can potentially affect the night vision devices. Another area of concern is vulnerability, and the possibility of medical equipment being detected from the outside of the aircraft. Once assessed, it may be possible to mitigate the harmful blooming effects by making recommendations for reducing or eliminating light signatures through the application of filters, concealment, or by other means. Depending on the operational scenarios adopted, there may be a need to develop a specific test standard for UAVs in casualty and medical applications. The information from available medical and aviation test standards by NATO Nations should be used as a baseline but needs to be tailored to UAVs.
- E) There is currently little if any routine transfer of data between NATO and Partner Nations regarding medical equipment or evacuation techniques which have been found either successful or unsuccessful.



NATO needs to address this issue in the near future, especially in light of current NATO efforts to develop multi-national medical support structures and medical support modularity. It appears that the Aeromedical Panel of the Air Board would be an appropriate body to develop such a reporting/comparison system, which should be made available to all Allied Nations.

## **7.4 SUMMARY**

In summary, there are many ongoing and necessary RDT&E initiatives for manned en route care, as well as for CASEVAC without en route care. The information gathered from those initiatives will be critical to the successful use of UAVs as life-saving platforms. Many knowledge and interoperability gaps remain that need to be addressed. With the help of this committee, the opportunity to save lives with UAV platforms is closer to reality.



## Chapter 8 – ETHICAL/LEGAL ISSUES

### 8.1 GENERAL

Both legal and ethical issues will of course impact decisions on the authorization of use for UAVs in either the CASEVAC or the MEDEVAC role. The RTG has considered these issues in great detail.

### 8.2 LEGAL ISSUES

We agree with the draft NATO Airworthiness Policy (2010) which states that:

*“Historically, military aircraft operate outside of the regulatory authorities, rules and regulations that civil aircraft must adhere to. Most of NATO Nations’ MODs have started to introduce an airworthiness framework similar to civil frameworks. Airworthiness is about achieving an acceptable known level of safety. It is a discipline that is concerned with the determination of whether or not an aeronautical product has achieved a state of being technically and operationally airworthy, and with the production of the evidence to this effect. It is usually supported by standards used to assess that such aeronautical products are fit and safe for flight, when operated within their design limits in conformance with their approved design type, manufacturing and maintenance standards. NATO is assumed liable for aeronautical products owned, leased or operated on their behalf. Meanwhile, NATO Member Nations have a legal and moral obligation to provide airworthy aeronautical products to their aircrew, passengers and to the third parties. However, there is a certain degree of disparity in airworthiness legal coverage and implementation among various NATO and Partner Nations.”*

We feel that this statement appropriately addresses some of the legal issues which must be faced in the UAV debate, though it does not address any specifically medical or clinical considerations which will affect this usage.

Additionally, the concept of placing humans of any status on UAVs may require legal or regulatory changes within the Nations or the EU. Currently, no certification agency has specific procedures for certification of such aircraft to carry humans. Many knowledgeable individuals feel that current regulatory schema will eventually permit such certification, though several mechanisms. Israel’s Urban Aeronautics feels they can get U.S. certification for their AirMule through de novo certification via FAR Part 27. Other people knowledgeable in the regulatory realm have opined that the easiest way to get certification will be through the issuance of a Supplemental Type Classification (STC) if the UAV is derived from a currently-certified Rotary Wing Aircraft. This issue is far beyond the capability of this RTG to resolve. We have had to assume that if Nations wish to make use of UAVs as evacuation aircraft they will figure out some legal way to make it happen.

### 8.3 ETHICAL ISSUES

From an ethical standpoint, the only real issues are whether the proposed use of the UAV in this way is in the best interests of the patient, and can be accomplished in a way which is designed to not increase the risks to an untoward degree. We have discussed elsewhere the concept of relative risk, which we feel is the primary issue at hand. The ethical guideline we must follow is “*primum non nocere*”<sup>1</sup>, and it is the opinion of the group that the appropriate use of UAVs for this purpose would not violate this standard.

---

<sup>1</sup> “First of all, do no harm”.

That being said, we reiterate that the manned air ambulance, with trained staff and care in flight, is the “gold standard” to which we all should aspire. Until new developments in closed loop control and other advanced medical technology make it feasible to replace the care in flight offered on a dedicated air ambulance, the use of any vehicle for MEDEVAC should not be considered. If MEDEVAC is available, it should always be the modality used to support our casualties, with CASEVAC being used only when MEDEVAC is not available, for whatever reason. If CASEVAC is decided upon, and if available UAVs meet the safety criteria we have discussed in Chapter 6, then UAV CASEVAC should be as acceptable as any other CASEVAC vehicle, and should not pose an ethical issue.

However, in addition to safety concerns, CASEVAC may not be a viable option for a particular evacuation based on ethical grounds. Different casualties will require different medical capabilities and treatments while en route, and will have received different levels of care up to extraction (anything from no care to advanced life support procedures performed before the UAV has been called in). The latter factor requires maintenance of relatively advanced medical capabilities in order to allow for safe extraction of pre-extraction treated casualties, while adhering to the ethical principle that does not allow lowering the standard of care given to a casualty over the chain of evacuation. This consideration may thus preclude use of a CASEVAC UAV in some cases on ethical grounds, in addition to separate safety concerns.

Other Ethical considerations, including continuity of care, a prohibition on transferring a patient to a lower level of care, and whether or not a medical attendant is needed to provide en-route care, seem to apply more to the concept of Medical Evacuation than to Casualty Evacuation. Therefore the use of a UAV for CASEVAC may be ethically justifiable, when its use would be of benefit to the casualty, and when the risks entailed are less than those of not providing the evacuation, even though such evacuation does not rise to the levels of care provided by true MEDEVAC.

## **Chapter 9 – CURRENT ADVANCES IN AIR EVACUATION AND THEIR APPLICABILITY TO UAVs**

### **9.1 CURRENT ADVANCES IN AEROMEDICAL EVACUATION**

Aeromedical Evacuation (AE) involves a wide spectrum of clinical care, utilising a range of aerial vehicles, to provide movement of ill and injured personnel from the point of wounding (or illness) to medical facilities, and between medical facilities. The goal of AE is to provide expedient movement, while delivering high quality and appropriate medical care during the transfer, if needed. Since the 1990 Gulf War, a reduction in the deployed medical footprint has been possible, largely due to improved aeromedical evacuation. Without this system, mortality and morbidity would have been increased, and deployed medical facilities would have been saturated. Today's aeromedical evacuation provides swift movement through medical facilities, reducing the overall need for bed spaces in the deployed environment. Rapidly mobile forces, with a light forward medical presence, rely heavily on the AE system, linking casualties to life-saving medical care<sup>1</sup>. Survival rates of traumatically injured personnel in Afghanistan are the highest in the history of warfare. This chapter sets out some of the recent advances in AE which have made these changes possible, and continues our evaluation as to whether UAVs have a role to play in this mission.

### **9.2 CASEVAC**

While much has been written about the medically supervised process of patient movement (MEDEVAC), there is little information about the conduct of CASEVAC. Kelly<sup>2</sup> reported the recent volumes of CASEVAC and MEDEVAC within the Afghanistan theatre (ISAF); the data is summarised in Table 9-1 below. Although the data prior to January 2010 is an under-estimate of actual volumes for a variety of reasons<sup>3</sup>, the data shows evidence of current CASEVAC movements. Kelly reported that the majority of CASEVAC movements were for low priority casualties, being moved on vehicles of opportunity. In addition to casualty movement by air, Kelly also reported that around 100 to 150 casualties were moved by ground CASEVAC each year. The documented presence of CASEVAC continuing to occur at this level has great significance to future evacuations using UAVs. Commanders have an expectation of an ability to use any vehicle as an opportunity to evacuate casualties, if the use of that vehicle does not in itself pose an imminent danger to the occupant. Cargo-carrying UAVs therefore could present a potential opportunity for CASEVAC movement, once they are present on the battlefield.

---

<sup>1</sup> Bloomquest, C.R. Use of quality tools to re-engineer the aeromedical evacuation (AE) system.

<sup>2</sup> Kelly, L. (SO2 Aeromed Operations, NATO ISAF Joint Commander). 19 October 2011. Personal Communication.

<sup>3</sup> An improved reporting system commenced in January 2010.

**Table 9-1: CASEVAC and MEDEVAC Within Afghanistan, 2009 – 2011.**

Date Range	Casualty Category	Numbers of Casualties / Patients Moved by Air				
		CASEVAC	Forward AE			Tactical AE (Non-US/UK)
			MERT <sup>4</sup>	Pedro <sup>5</sup>	Other Assets (Including UH-60)	
1 Jan – 30 Sep 2011	NATO	170	351	1294	4305	1558
	Non-NATO FF <sup>6</sup>	5	126	364	1870	956
	Civilian	1	135	417	1825	1125
	Enemy Combatants	2	21	68	128	110
1 Jan – 31 Dec 2010	NATO	No Data	329	870	1618	623
	Non-NATO FF	No Data	98	273	688	291
	Civilian	No Data	122	300	666	415
	Enemy Combatants	No Data	5	31	56	35
1 Jan – 31 Dec 2009	NATO	No Data	217	587	1783	1131
	Non-NATO FF	No Data	115	250	931	541
	Civilian	No Data	152	233	650	402
	Enemy Combatants	No Data	11	12	38	32

A further significant observation from the International Stabilization Assistance Force (ISAF) Joint Command (IJC) data is the presence of enemy combatant CASEVAC; there were two reported cases of enemy combatants moved by CASEVAC in 2011. The urgency of movement and severity of injury of these casualties was not known; however the CASEVAC movement of enemy combatants suggests battle injury as the origin of their injuries. Article 12 of the first Geneva Convention<sup>7</sup> mandates the non-discriminatory, humane treatment of all wounded and sick personnel; specifically, personnel should not be left without medical assistance and care.

**Potential UAV Use:** When cargo-capable UAVs are employed in the forward area, their first likely use as casualty movement platforms will be CASEVAC, as a vehicle of opportunity. If UAVs were to be used for future casualty or patient movement, their use could not be limited to that of friendly force or civilian personnel only; provision for the safe movement of enemy combatants would be required to comply with the requirements of The Geneva Conventions. (Chapter 3 provides more detail on this issue).

<sup>4</sup> UK Medical Emergency Response Team.

<sup>5</sup> USAF Combat Search and Rescue Aircraft and Medical Team.

<sup>6</sup> Non-NATO Friendly Forces.

<sup>7</sup> Geneva, I. Article 12.

### **9.2.1 CASEVAC and MEDEVAC in Afghanistan**

The preceding table provides information on the usage of both CASEVAC and MEDEVAC in Afghanistan during the period 2009 – 2011. It does not provide clean data concerning the relative usages of CASEVAC versus MEDEVAC because of some definitional problems. Both the UK MERT missions and those of the USAF “Pedro” teams are listed with MEDEVAC under “Forward Evacuation”. However, the Pedro aircraft are not dedicated to the aeromedical evacuation mission (their primary mission is Combat Search and Rescue rather than casualty evacuation), and thus these missions are technically CASEVAC rather than MEDEVAC. Although the argument is often made that nearly all evacuations are via MEDEVAC, it should be noted that approximately 1/3 as many evacuations were made by non-MEDEVAC means as by use of dedicated MEDEVAC. Even if we ignore the PEDRO missions, it is obvious that the use of CASEVAC in current operations is a common means of casualty evacuation.

### **9.2.2 MEDEVAC – General**

Ground and aeromedical evacuation services do not exist in isolation; their provision depends on the operational laydown of fixed medical facilities, the context of the operational environment and the MEDEVAC assets available to a Commander for deployment.

Thornton and Neubauer described the operational environment, provision of in-theatre medical capabilities and issues with aeromedical evacuation during the UN Protection Force (UNPROFOR) experience in the Former Yugoslavia<sup>8</sup>. The capabilities and number of Field Hospitals available to UNPROFOR were far less than those currently available to ISAF in Afghanistan. For UNPROFOR, ground evacuation was commonplace between the point of wounding and the first medical facility; further ground movement could also be utilised for movement to higher levels of care; for ISAF, however, the overwhelming majority of patient movements have been conducted via the air; ground evacuation rarely occurs, due to the terrain, distances to be covered, hostility and safety of patients. Thornton and Neubauer also noted the multi-national provision of MEDEVAC assets, detailing their team compositions and available equipment for use; the total number of assets and the medical capabilities available in Afghanistan today are considerably greater than those available in the Former Yugoslavia.

During UNPROFOR operations in the former Yugoslavia between June 1991 and 15 July 1994, from a Population At Risk (PAR) of 40,000, over 1,100 personnel were repatriated for medical reasons; there were 474 battle injuries<sup>9</sup>. For ISAF, the PAR in Afghanistan is currently over 130,000<sup>10</sup>; current numbers of medical evacuations in Afghanistan are proportionally far greater than the UNPROFOR experience and indeed other recent operations as discussed by Bruce<sup>11</sup>.

UK MEDEVAC data from the RAF Medical Operations Cell at HQ AIR<sup>12</sup> is summarised in Table 9-2; this details the number of patients moved by UK-provided CASEVAC and TACEVAC assets within Afghanistan.

---

<sup>8</sup> Thornton, W.P. and Neubauer, J.C. “United Nations Aeromedical Evacuation Operations in the Former Yugoslavia”.

<sup>9</sup> Ibid.

<sup>10</sup> ISAF Troop Contributing Nations [internet] 2011 October 18.

<sup>11</sup> Bruce, D.L. “Military CASEVAC from the Balkans to Basrah”.

<sup>12</sup> Gaffney, J.G. and Booker, C. (Deputy Assistant Chief of Staff, Medical Operations (RAF), HQ Air Command, United Kingdom). 2011 November 28. Personal communication.

**Table 9-2: UK-Provided Air Evacuation Within Afghanistan.**

Date Range	Numbers of Casualties / Patients Moved by Air		
	Forward AE	Tactical AE	
	MERT	Tac CCAST	Tac AE
1 January – 30 September 2011	674	99	803
1 January – 31 December 2010	1457	150	1299
1 January – 31 December 2009	901	105	935

### 9.2.3 Forward Aeromedical Evacuation

Trauma is defined as physical injury<sup>13</sup>. The “golden hour”, a concept described by the American College of Surgeons Advanced Trauma Life Support training<sup>14</sup>, has been fully embraced within the deployed, pre-hospital trauma care environment.

#### 9.2.3.1 Catastrophic Haemorrhage

The tri-modal distribution of death following traumatic injury identifies three peaks in the number of deaths when plotted as a function of time; within the first peak, immediate deaths, are characterized by lacerations of the brain, the brain stem, the spinal cord, the heart or one of the major blood vessels<sup>15</sup>. In the combat-traumatically injured, exsanguination, or catastrophic hemorrhage, is the primary threat to life; it is preventable. In recognition of the preventable nature of death by catastrophic haemorrhage, a new phrase was born: “the platinum ten minutes<sup>16</sup>”. Within this immediate post-traumatic period, interventions are possible to prevent a certain outcome of death and form Pre-Hospital Trauma Life Support (PHTLS) as practiced today. Forward-delivered medical care has evolved to improve the treatment of trauma, encompassing the trauma-care requirements of the “platinum ten minutes”: personnel are trained in first-aid techniques<sup>17</sup>; they are provided with Combat Application Tourniquets (CATs) and the Israeli First Field Dressing (FFD). Trauma care can start with the affected individual (“self-aid”) or their associates (“buddy aid”). Combat medics, trained in advanced techniques<sup>18</sup>, are available on the ground to enhance pre-hospital trauma care delivery. CATs, FFDs and haemostatic agents are highly effective means of stopping catastrophic hemorrhage; these simple interventions have increased survival at the point of injury<sup>19</sup>.

<sup>13</sup> Concise Oxford English Dictionary. 11<sup>th</sup> Ed.

<sup>14</sup> Fildes, J. History of the ATLS® program.

<sup>15</sup> Trunkey, D.D. Trauma.

<sup>16</sup> Calland, V. Extrication of the Seriously Injured Road Crash Victim.

<sup>17</sup> Donaldson, P. Military First Aid Kits.

<sup>18</sup> United Kingdom. Ministry of Defence. Clinical Guidelines for Operations.

<sup>19</sup> Russell, R.J., Hodgetts, T.J., McLeod, J., Starkey, K., Mahoney, P., Harrison, K. and Bell, E. The role of trauma scoring in developing trauma clinical governance in the Defence Medical Services.

### **9.2.3.2 Early Intervention – Rapid Evacuation**

In Afghanistan and within the “golden hour”, early intervention by highly specialised medical teams and/or rapid evacuation of the traumatically injured to expert help is provided by a range of forward aeromedical evacuation assets. British Medical Emergency Response Teams (MERT) are one such highly capable asset; they fly to the point of wounding on a CH-47 Chinook helicopter. MERT aims to provide high quality pre-hospital trauma care and rapid patient movement from as far forward as the tactical situation permits, to the first appropriate medical facility. MERT comprises a highly trained team (a doctor trained in pre-hospital care, emergency nurse and two state registered paramedics) with specialised capabilities. Their capabilities have evolved to treat the leading causes of death in the traumatically injured.

### **9.2.3.3 Hypovolaemia, Acidosis and Hypothermia**

A lethal triad of blood loss, acidosis and hypothermia exists and is a significant obstacle in the treatment of trauma<sup>20</sup>. MERT treatment capabilities project the resources of the emergency department forward in time and place; their treatments directed at combating components of this triad. In the treatment of hypovolaemia, when intravenous access cannot be obtained, intra-osseous access can be achieved by the use of intra-osseous needle and infusion systems; Cooper et al have demonstrated the highly successful use and effective nature of these systems<sup>21</sup>. Blood loss can be replaced from the four units of blood and four units of plasma that are carried on-board. When considering the treatment of metabolic acidosis, sodium bicarbonate could be used, however there is little rationale for its use and no evidence of its effectiveness in general or in the trauma setting; other pharmacological treatments are currently being investigated<sup>22</sup>. In addition to trauma, hypothermia can be worsened by the flight environment; MERT has three mechanisms to improve hypothermia: an intravenous fluid and blood warming system, a survival blanket, and a patient heating system. Schmelz et al. have demonstrated the effectiveness of hypothermia prevention during AE, following resuscitation from hypovolaemic shock<sup>23</sup>. In conjunction with the improvements in trauma care given at fixed medical facilities, these highly capable forward aeromedical evacuation assets have intuitively improved overall trauma care by increasing survival and reducing mortality in the deployed environment<sup>24,25</sup>.

### **9.2.3.4 Forward AE Tasking**

Other forward aeromedical evacuation capabilities are available but are provided on smaller aircraft platforms, e.g. UH-60; these are present in greater numbers than is MERT. Their higher relative availability offers the benefit of rapid evacuation to expert help. Forward aeromedical evacuation assets are controlled by medical personnel; based on the information received within MEDEVAC requests, the most appropriate and available asset can be tasked to perform the mission. There is a wide range of assets: those that are high in number offering speed as their greatest quality, e.g. Pedro on the HH-60, to those that are smaller in number, offering highly specialised care, but which have a slower airspeed, e.g. the MERT on the CH-47. This is of great

---

<sup>20</sup> Lynn, M., Jeroukhimov, I., Klein, Y. and Martinowitz, U. Updates in the management of severe coagulopathy in trauma patients.

<sup>21</sup> Cooper, B.R., Mahoney, P.F., Hodgetts, T.J. and Mellor, A. Intra-osseous access (EZ-IO®) for resuscitation: UK military combat experience.

<sup>22</sup> Jansen, J.O., Thomas, R., Loudon, M.A. and Brooks, A. Damage control resuscitation for patients with major trauma.

<sup>23</sup> Schmelz, J.O., Bridges, E.J., Wallace, M.B., Sanders, S.F., Shaw, T., Kester, N., Bauer, S. and Sylvester, J.C. Comparison of three strategies for preventing hypothermia in critically injured casualties during aeromedical evacuation.

<sup>24</sup> Russell, R.J. et al. Op.cit.

<sup>25</sup> Russell, R. Emergency Care on the Battlefield.



benefit, both to the casualties and to the aviation managers, as a tailored response can be provided for the movement of patients from the forward area.

#### **9.2.3.5 Potential UAV Use**

Provided that casualty movement within the vehicle causes no harm, UAVs certainly have the potential to be used for CASEVAC. Thus, UAVs could add to existing available options for the opportune movement of casualties in operations, and should be considered for this use when they are available. UAVs could perform MEDEVAC if the payload could accommodate a medical team and equipment. Increasing levels of payload would permit enhanced levels of care to be provided, or an increased number of patients transferred per mission.

When cargo-capable UAVs commence employment in the forward areas, their internal size and payload will likely restrict their initial medical use to the CASEVAC role. However, with development, a greater internal size and available payload could potentially offer the ability to perform the MEDEVAC role (see Chapter 2 and Annex D); if this development were to occur, another available option would be accessible to solve the forward patient movement problem. Annex E considers the potential future use of UAVs for tactical and strategic aeromedical evacuation.

## Chapter 10 – SUMMARY AND RECOMMENDATIONS TO COMEDS AND RTO

The new NATO Force Structure is built to enable deployment of multi-national forces to any area in NATO's area of interest, for any mission. This requires an integrated multi-national healthcare system able to establish and to maintain high quality preventive, primary, restorative and trauma healthcare as well as an effective extraction/evacuation system from the battlefield throughout all the roles of medical care.

Unmanned aerial platforms have proved their effectiveness over a modern battlefield in the ISTAR mission field. Current rapid technological developments will ensure that UAVs will play a more important operational role in both combat and humanitarian missions. This includes the potential to use those platforms not only for ISTAR but also for personnel transport. However the maturity of technology is one thing, the acceptance of the technology is another – both still have some way to go before this development can be fully accepted. UAV operations are also getting safer – the U.S. PREDATOR accident rate is down to 7.5 accidents per 100,000 flight hours, which is comparable to the U.S. F-16 accident rate (single seat manned aircraft)<sup>1</sup>.

Almost 1/3 of U.S. military aircraft are currently unmanned (31%),<sup>2</sup> and this trend is expected to continue for the foreseeable future. While most of these UAS are fixed-wing, the number of rotary wing or VTOL UAS is also increasing as UAS and VTOL propulsion and lift technologies improve. The U.S. Army's UAS roadmap predicts that 25 per cent of all cargo missions will be flown by unmanned rotary wing platforms by 2020. By 2025 the integration of Optionally Piloted Vehicles (OPV) technology into all of the Army's rotary-wing aircraft should be finalized. In this transition phase, we believe that we will see human transport with OPV technology, as these platforms are "man rated" when flown by pilots and therefore they demonstrate identical safety standards to those of their manned RW counterparts. The only difference is that they are flown without a pilot on board. We do not ignore the very real operational challenges to such use which must be met, to include terrain and obstacle avoidance, aircraft survivability, communications, C4, and airspace control, but we note that significant and productive efforts to resolve each of these issues are making excellent progress.

We assume that research and technological progress will create in the near future smart algorithms which will support the human operator with automatic analysis for easier decision-making. Thus, given enough time, it seems to be realistic to identify military situations in which UAVs might be useful for casualty extraction.

The evolution of rotary wing unmanned aerial vehicles means that they are now challenging the limitations of their manned counterparts, providing tactical advantages and flexibility both on land and at sea. This potentially opens the way for casualty extraction using UAVs. It has to be noted that we consider that a planned and coordinated evacuation program using UAVs embedded in an overall medical support concept, cannot be implemented at this time, due to technological gaps and documented safety limitations, as mentioned above. However, as Logistics/Cargo UAVs make their appearance in the field, we see no reasons to assume that they cannot or should not be used as a CASEVAC transport mechanism when this would be to the benefit of the casualty. There seem to be no Legal, Ethical, Doctrinal, Technical, or Clinical reasons that the use of UAVs should not be seen as a viable alternative means of evacuation. No currently developmental Cargo UAV is currently considered to be suitable for use in the MEDEVAC role, but this RTG sees no reason to assume that such a role is out of the question for future use, as technological development

---

<sup>1</sup> "U.S. Unmanned Aerial Systems".

<sup>2</sup> "U.S. Unmanned Aerial Systems". Note that these numbers include small UAS like the U.S. Army's RAVEN.

## SUMMARY AND RECOMMENDATIONS TO COMEDS AND RTO

---

continues. There is no new “science” required to successfully develop and field a VTOL UAS with Medical Mission capability. However, there is a significant amount of engineering required for integration; to decrease size, weight and power requirements; and to reduce costs. There are no technical roadblocks to developing and fielding a VTOL UAS medical mission capability. There are cultural/acceptance, policy and doctrine issues to be addressed. This isn’t a new challenge – We need only to look back to the early days of intercontinental missile deployment, and the opposition this development faced from the manned bomber community. The importance of public acceptance of the concept is demonstrated by the automatic elevator, which for many years had to be “manned” with an operator to punch the buttons, since the general public would not accept a machine without an operator.

In summary, it appears to us that the potential use of UAVs for the movement of casualties is a timely issue for discussion and policy development, and will be operationally feasible in the short to medium term. The increasing numbers and types of Unpiloted Vehicles on the Battlefield, along with their increasing capabilities, clearly imply that the day may soon come when a UAV is present in a location at which a casualty needing immediate evacuation is also found, and who for various reasons cannot be evacuated by a dedicated Medical Evacuation aircraft. If an operational situation arises in which an extraction of casualties by other means is not possible, it is likely that we will see the unplanned use of UAVs for CASEVAC as “ultima ratio” to save lives in the near future. Such a use will be based on the decision of a given military commander to act in accordance with the need to take care of his casualties, regardless of policy or planning. Consideration of, and development of doctrine for, this new concept needs to be done in fairly short order, or someone in the field will execute one of these medical missions with a cargo VTOL UAS and NATO will have to very quickly “backfill” policy and doctrine.

This potential scenario leads to several questions which must be addressed:

- Can the casualty be transported by the UAV?
- Can the risk involved be mitigated by proper training, planning, and equipment development?
- What characteristics of UAVs need to be taken into account in making these determinations?

Our conclusion is that the use of UAVs for casualty evacuation in the short to medium term (within 5 – 15 years) will be both practical and likely, and in certain operational scenarios may prove to be the only practical option available. There is no doubt that there will be risk involved, and also no doubt that at times this risk could conceivably be less than the option of not moving the casualty at all. It is our belief that, like it or not, SUCH USE OF UAVs for CASEVAC WILL TAKE PLACE AS SOON AS CARGO UAVs OR OPTIONALLY-PILOTED CONVENTIONAL AIRCRAFT ARE AVAILABLE ON THE BATTLEFIELD – It is up to NATO and the Nations to ensure that such use is carried out under the safest possible conditions.

We have identified some characteristics of UAVs which must be taken into account before deciding to use them for evacuation (see Chapter 6). In most cases, especially in the short term, such usage will have to be in the absence of medical equipment or care in flight. The ability to provide care in flight and medical equipment suitable for the MEDEVAC role in a UAV is simply not technologically feasible at the current time, though conceptually it is certainly not impossible in the medium to distant term.

It is not our conclusion that these aircraft can or should replace the current “gold standard” – the piloted air ambulance with a medical crew and appropriate medical equipment (Medical Evacuation). In fact, given the current state of development of medical equipment, we feel that such replacement is impossible at this time, without the acceptance of reduced patient safety and potentially worsened clinical outcomes. While

conceptually the replacement of manned air ambulances with UAVs is possible, we do not believe it will be possible or desirable in the short or medium term. We have identified some in-flight care capabilities and medical equipment which would be desirable if future development of a UAV dedicated to MEDEVAC use is decided upon (see Chapter 5 and Annex D).

Therefore, we have chosen to approach the problem from the viewpoint of “Given the availability of a UAV with adequate capability to move a casualty in CASEVAC mode, how can the unit commander on the ground analyze the relative risks and make a determination in an individual case as to whether or not to use such a vehicle”. Therefore, we have emphasized principles to assist in making those determinations, rather than prescriptive SOPs. We have developed some criteria for casualty preparation and selection, which should be considered before making the decision to evacuate a casualty by this means (see Chapter 6). These criteria include:

- The aircraft must meet all the same safety-of-flight requirements as do current manned Rotary Wing Aircraft;
- Environmental Standards in the casualty compartment (e.g. noise, vibration, acceleration factors, air quality) must be met in accordance with current standards;
- Some provision must be made to fix the casualty to the aircraft (e.g. litter tie-downs); and
- Carriage of the casualty must be internal to the aircraft.

We have developed recommendations for more clinical, technical, and operational research and development which is needed to provide more data which will support effective evacuation, regardless of the type of aircraft involved. These criteria need to be formalized and made part of NATO medical and operational doctrine, and should be incorporated into appropriate NATO training courses, such as those of the Military Medical Center of Excellence, the NATO Special Operations Headquarters, and the NATO School at Oberammergau. This is necessary whether we are discussing UAVs in the sense of future fully autonomous vehicles, piloted by on-board artificial intelligences, or in the sense of a remotely piloted aircraft, with the human pilot physically located at some distance.

We have tried to avoid getting into the “design a UAV air ambulance” mindset, and have concentrated our efforts on understanding what current and near-term UAV logistics aircraft can and will be able to do, and how they might be limited in the CASEVAC mode. We have constantly reminded ourselves that we are not building a specific aircraft, but looking at how to most effectively use any of several potential candidates which might be available on the field of battle. The impact of performance on patient safety is the critical issue. Various options have been discussed, including understanding or limiting the flight parameters of the aircraft. We have looked at both hardware restrictions (e.g. “must meet all the same safety and flight parameter restrictions as current Rotary Wing aircraft used for evacuation”) as well as software capabilities (e.g. a switch or button which can change flight parameters from those normally used to some which are safe for carrying casualties).

## **10.1 RECOMMENDATIONS**

Thus, HFM-184 specifically recommends that:

- The UAV safety parameters found in Chapter 6 be adopted as a starting point for the development of NATO doctrine on this subject. These parameters should be included in all NATO doctrinal documents addressing this issue.

## SUMMARY AND RECOMMENDATIONS TO COMEDS AND RTO

---

- The research areas identified in Chapter 7 be pursued by both the Alliance and the various Nations, to ensure that all evacuation, whether by manned or unmanned aircraft, will be carried out without detriment to the casualties. With specific reference to needed research on the issue of vibration and shock exposure criteria, with specific reference to the evacuation of neck and spine injuries (as addressed in Chapter 7, above), we recommend that the RTO should develop and support a Symposium addressing this single issue, in the near future.
- There is a significant need for exchange of medical research results in this arena of Combat Casualty Care which cannot be satisfied by any current NATO body. We recommend that COMEDS consider establishing a forum for the routine exchange of medical research results in casualty care. Obviously, the Military Health Care WG and the Emergency Medicine WG must be involved in this effort, but we feel that a specific forum for the exchange of operational military medical research results should be established. It is possible that the pre-existing forum “NATO Operational Medicine Course” could be tasked to routinely undertake this task.
- There is a distinct need for some standing NATO group to be tasked to monitor developments in this field of UAV development from the medical viewpoint, and to take the lead in developing the necessary doctrine for the use of this type of aircraft within the medical arena. While conceptually, this could be tasked to one of the standing technical groups (such as the Joint Capability Group on Unmanned Aerial Vehicles), it is critical that this group should include both clinicians and medical planners, which the JCGUAS does not have currently, thus we recommend that this task should be allocated to the Aeromedical Working Group of the NSA Air Board.
- This concept of Logistics UAVs and their potential uses should be further developed by the NATO JCGUAS/JUASP, The Committee of the Chiefs of the Military Medical Services in NATO (COMEDS), The NSA Air Board with its Aeromedical Panel, Allied Command Transformation (ACT) and Allied Command Operations (ACO), each in their own areas of expertise. Further, we recommend that such future potential use of UAVs for this purpose be specifically written into NATO doctrine, along with its limitations.
- To preclude “field expedient” use of a UAV for casualty evacuation, possibly to the detriment of the casualty, we specifically recommend that the Aeromedical Panel of the NSA Air Board should begin to consider this issue, and begin development work on an appropriate Standardisation Document to address the issue of CASEVAC in UAVs. We consider that the Aeromedical Panel is the best NATO clinical body to address this issue, in conjunction with the Military Health Care and Emergency Medicine WGs, as well as the JCGUAS/JUASP.
- Changes to MC-326/3, AJP-4.10 (B), AJMEDP-2, and other relevant documents should be developed and promulgated by the custodians of these documents (in accordance with recommendations herein) to ensure that when such use occurs it will do so in a controlled and patient-beneficial way. If it becomes feasible in the future to actually use such airframes for MEDEVAC purposes (i.e. to carry medical personnel and/or equipment to provide care in flight), it will be necessary to amend STANAG 2087 to include guidance on such use. Custodians for these documents are strongly encouraged to begin development of such doctrine now, rather than waiting until cargo UAVs are present on the battlefield and the issue becomes moot. Those Nations which do not have doctrine expressly addressing the issue of CASEVAC may wish to consider development of such doctrine. We believe that this is an opportune time for the COMEDS and the NATO Standardisation Agency specifically task the relevant standardisation bodies to begin work on development of these documents as recommended above.
- NATO (Allied Command Operations) directives must be developed which will give guidance to commanders on this decision-making issue (to be considered after consultation with medical authorities in the theater of operations).

- ATP-3.3.7 should be amended to ensure that operations around Logistics UAVs (whether in CASEVAC or logistics use) are safe, to include specific training requirements for non-UAV operators who will have to work around and near UAVs (specifically, medics and combat soldiers). Further, we recommend that training requirements and guidelines for patient stabilization prior to CASEVAC on any type of vehicle be elucidated and published in the near future. This task could be most usefully assigned to the Emergency Medicine WG.
- A COMEDS effort be instigated to improve the transfer of data between NATO and Partner Nations regarding medical equipment or evacuation techniques which have been found to be either successful or unsuccessful. Unfortunately, the NATO Joint Allied Lessons Learned Center does not seem to be effectively used for the transmission of medically-related lessons learned. COMEDS needs to address this issue in the near future, especially in light of current NATO efforts to develop multi-national medical support structures and medical support modularity. It appears that the Military Medical Center of Excellence would be an appropriate body to develop such a reporting/comparison system for evacuation lessons learned, which should be made available to all Allied Nations.
- This issue be added to the list of items for consideration and further development in the Military Medical planning domain. We note that “Military Medical” has been recognised as one of the NATO planning domains and has been introduced into the NATO Defence Planning Process to reflect the growing demand for, and to exploit the opportunities rendered by a NATO-wide coordinated capability planning and development effort in support of the Alliance’s Level of Ambition. It seems to this RTG that the whole issue of UAVs in the CASEVAC context presents an excellent opportunity for forward thinking efforts in the “planning and development effort”.
- The items listed under LTCRs (Long-Term Capability Requirements) M-3 and L-9 be expanded to specifically mandate consideration of the issue of CASEVAC by UAS.
- The Joint en route Care Equipment Test Standard (JECETS) document, currently being developed on a U.S.-only level be considered for NATO standardisation. Once JECETS is finalized, it would appear useful to discuss it within the NATO Aeromedical community, with the objective of gaining agreement to standardizing these processes as an Allied Medical Publication. There is a distinct need for increased NATO standardization in this regard. Again, the Aeromedical Panel would seem to be the optimum body to be tasked to accomplish this development, as some of their current standardisation documents are already relevant to this issue.
- There is currently little if any transfer of data between NATO and Partner Nations regarding medical evacuation equipment or techniques which have been found either successful or unsuccessful. NATO needs to address this issue in the near future, especially in light of current NATO efforts to develop multi-national medical support structures and medical support modularity. It appears that the Aeromedical Panel of the Air Board would be an appropriate body to develop such a reporting/comparison system, which should be made available to all Allied Nations.
- RTO plan support for a RTO symposium or specialists’ meeting on progress in the field of UAV evacuation, to be held in approximately three years, to monitor new developments and lessons learned.

In conclusion, the RTG is convinced that in the future we will routinely see the use of UAVs for casualty evacuation as technological innovation solves the described shortfalls and limitations, with CASEVAC being feasible in the short-to-medium term, and MEDEVAC following only in the more distant future. Medical clinicians and medical planners are called upon now to follow the technological development and to bring in their expertise and knowledge to bear in ensuring that such potential use will be able to benefit the soldiers whom we serve. We, and our future casualties, cannot afford to disregard such a potentially lifesaving technology.





## Chapter 11 – REFERENCES

For ease of reference, the Reference List has been divided into several sub-sections. These are:

- 1) Administrative/Certification/Legal/Ethical Documents;
- 2) Clinical and Operational Documents;
- 3) Concept/Doctrinal Documents;
- 4) Engineering References/Standards;
- 5) Miscellaneous;
- 6) NATO Documents; and
- 7) Status of Development of UAS.

### 11.1 ADMINISTRATIVE/CERTIFICATION/LEGAL/ETHICAL DOCUMENTS

Commission on Accreditation of Medical Transport Services, “8th Edition Accreditation Standards (draft)”. Sandy Springs, North Carolina. 10 July 2010.

Eurocontrol, “Eurocontrol Specification 0102 – Eurocontrol Specifications for the Use of Military Unmanned Aerial Vehicles as Operational Air Traffic Outside Segregated Airspace”. 26 July 2007.

International Committee of the Red Cross, “Protocols Additional to the Geneva Conventions of 12 August 1949”. Geneva. 1987.

International Committee of the Red Cross, “The Geneva Conventions of August 12, 1949”. Geneva. 1989.

United States Army AMEDD Center and School, “Memorandum: Use of Robotic Vehicles for CASEVAC”, 7 June 2006.

United States Department of Defense, “Dictionary of Military Terms and Associated Terms (JP 1-02)”, 12 April 2001 (amended 4 March 2008).

United States Department of Transportation, “Federal Specification for the Star-of-Life Ambulance KKK-A-1822E”. United States General Services Administration, Washington, D.C. 1 June 2002.

United States Federal Aviation Administration, “Order 8130.2F – Airworthiness Certification of Aircraft and Related Products”. 5 November 2004.

United States Federal Aviation Administration, “Order 8130.34 – Airworthiness Certification of Unmanned Aircraft Systems”. 27 March 2008.

United States Federal Aviation Administration, “Federal Air Regulations, Part 23 (14 CFR), Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes”.

United States Federal Aviation Administration, “Federal Air Regulations, Part 25 (14 CFR), Airworthiness Standards: Transport Category Airplanes”.

## REFERENCES

---

United States Federal Aviation Administration, “Federal Air Regulations, Part 27 (14 CFR), Airworthiness Standards: Normal Category Rotorcraft”.

United States Federal Aviation Administration, “Federal Air Regulations, Part 29 (14 CFR), Airworthiness Standards: Transport Category Rotorcraft”.

United States Federal Aviation Administration, “Federal Air Regulations, Part 36 (14 CFR), Noise Standards: Aircraft Type and Airworthiness Certification”.

United States Federal Aviation Administration, “Regulation US Code, 14 CFR 91.113b – General Operating and Flight Rules”.

United States Federal Aviation Administration, “Unmanned Aerial Vehicles Human Factors”. 2005.

United States Federal Aviation Administration, “UAV Safety Checklist – 8130.34”. 19 September 2008.

## 11.2 CLINICAL AND OPERATIONAL DOCUMENTS

Aerospace Medical Association Air Transport Committee, “*Medical Guidelines for Airline Travel*”, Alexandria, VA, 1997.

Aldous, J. (executive producer), “Frontline Medicine – Survival” [TV episode]. London: British Broadcasting Corporation; 20 November 2011.

Allan, P.F., Osborn, E.C., Bloom, B.B., Wanek, S. and Cannon, J.W., “The Introduction of Extracorporeal Membrane Oxygenation to Aeromedical Evacuation”. *Military Medicine*. 2011; 176(8):932-937.

American Academy of Orthopedic Surgeons, “Emergency Care and Transportation of the Sick and Injured”. 2004.

Baker, C.F., “Sensory Overload and Noise in the ICU: Sources of Environmental Stress”. *Critical Care Quarterly*. 1984 March; 6(4):66-80.

Barnes, S.L., Branson, R., Gallo, L.A., Beck, G. and Johannigman, J.A., “En-Route Care in the Air: Snapshot of Mechanical Ventilation at 37,000 Feet”. *J Trauma*. 2008;64:S129-S135.

Ben-Galim, P., Dreiangel, N., Mattox, K.L., Reitman, C.A., Kalantar, S.B. and Hipp, J.A., “Extrication Collars Can Result in Abnormal Separation Between Vertebrae in the Presence of a Dissociative Injury”. *J Trauma-Injury Infection and Critical Care*. 69(2): 447-450, August 2010.

Beninati, W., Meyer, M.T. and Carter, T.E., “The Critical Care Air Transport Program”, *Crit Care med*. 2008; 36(7(Suppl.)):S370-S376.

Bloomquest, C.R., “Use of Quality Tools to Re-Engineer the Aeromedical Evacuation (AE) System”. In: Rödiger E, (technical evaluator). “Proceedings of Advisory Group for Aerospace Research and Development Conference 554 on Recent Issues and Advances in Aeromedical Evacuation (MEDEVAC)”; 1994 October 3-7; Athens, Greece: 1-1 – 1-4.

Boyd, C.R., “Air Versus Ground Transportation”. *Journal of Trauma*, 1989, 29:789-94.

- British Thoracic Society Emergency Oxygen Guideline Group, "Guideline for Emergency Oxygen Use in Adult Patients". Thorax. Vol. 63 Supplement VI October 2008.
- Bruce, D.L., "Military CASEVAC from the Balkans to Basrah" [Diploma in the Medical Care of Catastrophes thesis]. Worshipful Society of Apothecaries, London. 2005.
- Calland, V., "Extrication of the Seriously Injured Road Crash Victim". Emerg Med J. 2005 November; 22(11):817-821.
- Cooper, B.R., Mahoney, P.F., Hodgetts, T.J. and Mellor, A., "Intra-Osseous Access (EZ-IO®) for Resuscitation: UK Military Combat Experience". JR Army Med Corps. 2007 December; 153(4): 314-316.
- Dahlgren, B.-E., Hogberg, R. and Nilsson, H.G., "Portable, But Suitable: Devices in Prehospital Care Might Be Hazardous to Patient or to Aviation Safety". Prehospital and Disaster Medicine, 1997 Jan-Mar;12(1):64-67.
- Donaldson, P., "Military First Aid Kits". G3 Defence. 2011, October; 3(5):46-48.
- Dorlac, G.C., Fang, R., Pruitt, V.M., Marco, P.A., Stewart, H.M., Barnes, S.L. and Dorlac, W.C., "Air Transport of Patients with Severe Lung Injury: Development and Utilisation of the Acute Lung Rescue Team". J Trauma. 2009 April; 66: S164-171.
- Elliott, R. et al, "Spine Immobilization In Penetrating Trauma: More Harm Than Good?". The Journal of Trauma, Injury, Infection, and Critical Care. Volume 68, Number 1, January 2010.
- Fang, R., Allan, P.F., Womble, S.G., Porter, M.T., Sierra-Nunez, J., Russ, R.S., Dorlac, G.R., Benson, C., Oh, J.S., Wanek, S.M., Osborn, E.C., Silvey, S.V. and Dorlac, W.C., "Closing the 'Care in the Air' Capability Gap for Severe Lung Injury: The Landstuhl Acute Lung Rescue Team and Extracorporeal Lung Support". J Trauma. 2011; 71:S91-S97.
- Fang, E., Dorlac, W.C., Flaherty, S.F., Truman, C., Cain, S.M., Popey, T.L.C., Villard, D.R., Aydelotte, J.D., Dunne, J.R., Anderson, A.M. and Powell, E.T., "Feasibility of Negative Pressure Wound Therapy During Intercontinental Aeromedical Evacuation of Combat Casualties". J Trauma. 2010 July; 69:S140-S145.
- Featherstone, R.L., "Determination of Critical Factors in Unmanned Casualty Evacuation in the Distributed Environment", United States Naval Postgraduate School, Monterey, California. June 2009.
- Fildes, J., "History of the ATLS® Program" [internet]. [cited 2011 December 11]. Available from: <http://www.facs.org/trauma/atls/history.html>.
- Flanagan, J.C., "The Critical Incident Technique". Psychological Bulletin, 1954:51, 327-358.
- Folds, D.J. and Martindale, V.E., "Human Systems Integration in Expeditionary Medical Treatment Facilities". Paper presented at NATO Use of Advanced Technology and New Procedures in the Medical Field Symposium and published in RTO-MP-HFM-182. NATO RTO Paris April 2010.
- Gaffney, J.G. and Booker, C. (Deputy Assistant Chief of Staff, Medical Operations (RAF), HQ Air Command, United Kingdom), Personal communication. 2011 November 28.
- Hadley, M.N., "Cervical Spine Immobilization Before Admission to the Hospital". Neurosurgery, Vol. 50(3): S7-S17, March 2002.

## REFERENCES

---

- Hadley, M.N., et al, "Transportation of Patients with Acute Traumatic Cervical Spine Injuries". Neurosurgery, Vol. 50, No. 3, March 2002.
- Haut, E.R., Kalish, B.T., Efron, D.T., Haider, A.H., Stevens, K.A., Kieninger, A.N., Cornwell, E.E. and Chang, D.C., "Spine Immobilization in Penetrating Trauma: More Harm Than Good?". The Journal of Trauma, Volume 68 #1, January 2010: 115-121.
- Hurd, W.W. and Jernigan, J.G., "Aeromedical Evacuation: Management of Acute and Stabilized Patients", Springer, 2003.
- Jernigan, J.G., "Aircraft Considerations for Aeromedical Evacuation", in Hurd and Jernigan, "Aeromedical Evacuation: Management of Acute and Stabilized Patients", Springer, 2003. 88-110.
- Kelly, L., (SO2 Aeromed Operations, NATO ISAF Joint Commander). Personal Communication. 19 October 2011.
- Kwan, I., Bunn, F. and Roberts, I., "Spinal Immobilization for Trauma Patients (Review)". Cochrane Library. 2008; 1-19.
- Lador, I. and Ben-Galim, P., "Motion Within the Unstable Cervical Spine During Patient Maneuvering: The Neck Pivot-Shift Phenomenon". J Trauma-Injury Infection and Critical Care. January 2001; 70(1):247-251.
- Lamb, D., "Collaboration in Practice – Assessment of an RAF CCAST". British Journal of Nursing. 2006; 15(10): 552-556.
- Lynn, M., Jeroukhimov, I., Klein, Y. and Martinowitz, U., "Updates in the Management of Severe Coagulopathy in Trauma Patients". Intensive Care Med. 2002 October; 28 Suppl 2:S241-7.
- McGuire, N.M., "Monitoring in the Field". British Journal of Anaesthesia, 2006. 97(1), 46-56.
- Miller, D. and Lawton, C., "Human Performance Modeling for System of Systems Analytics: Combat Performance-Shaping Factors". Retrieved from <http://prod.sandia.gov/techlib/access-control.cgi/2006/067911.pdf>.
- Mollan, I.A., (Coalition Validating Flight Surgeon, Joint Patient Movement Requirements Center, USCENTCOM September – November 2010), "US Bagram Aeromedical Evacuations with Wound Vac or Patient Controlled Analgesia (PCA)". 2010 October 30.
- No Authors Listed, "Transportation of Patients with Acute Traumatic Cervical Spine Injuries". Neurosurgery. 2002 March; 50 (3 Suppl):S18-20.
- Parmet, A.J., "Aviation Medicine", Clinics in Occupational and Environmental Medicine, 2002, Vol. II: 81-91.
- Parsons, K.C., "Environmental ergonomics: A Review of Principles, Methods and Models". Applied Ergonomics Volume 31, Issue 6, December 2000: 581-594.
- Rayman, R.B. and Williams, K.A., "The Passenger and Patient in Flight". In, Fundamentals of Aerospace Medicine, 3<sup>rd</sup> Edition 2002:453-469.

- Remick, K.N. et al, "Transforming U.S. Army Trauma Care: An Evidence-Based Review of the Trauma Literature". United States Army Medical Department Journal, July-September 2010: 4-21.
- Renz, E.M., "Aeromedical Evacuation of Burn Patients from Iraq". J Trauma. 2007;62:S74.
- Russell, R., "Emergency Care on the Battlefield". [internet]. [cited 2011 December 11]. Available from: <http://www.nhs.uk/Livewell/Militarymedicine/Pages/Survivingbattlefield.aspx>.
- Russell, R.J., Hodgetts, T.J., McLeod, J., Starkey, K., Mahoney, P., Harrison, K. and Bell, E., "The Role of Trauma Scoring in Developing Trauma Clinical Governance in the Defence Medical Services". Phil. Trans. R. Soc. B. 2011 January; 366: 171-191.
- Schmelz, J.O., Bridges, E.J., Wallace, M.B., Sanders, S.F., Shaw, T., Kester, N., Bauer, S. and Sylvester, J.C., "Comparison of Three Strategies for Preventing Hypothermia in Critically Injured Casualties During Aeromedical Evacuation". Military Medicine. 2007 March; 172(3):322-326.
- Schoenfeld, A.J., Goodman, G.P. and Belmont, P.J. Jr, "Characterization of Combat-Related Spinal Injuries Sustained by a U.S. Army Brigade Combat Team During Operation Iraqi Freedom". The Spine Journal. 10, 2010.
- Stevens, P.E., Bloodworth, L.L. and Rainford, D.J., "High Altitude Haemofiltration". BMJ. 1986 May 29; 292:1354.
- Stockinger, Z.T. and McSwain, N.E. Jr, "Prehospital Supplemental Oxygen in Trauma Patients: Its Efficacy and Implications for Military Medical Care". Military Medicine 2004 August; 169(8):609-12.
- Thornton, W.P. and Neubauer, J.C., "United Nations Aeromedical Evacuation Operations in the Former Yugoslavia". In: Rödiger E (technical evaluator). "Proceedings of Advisory Group for Aerospace Research and Development Conference 554 on Recent Issues and Advances in Aeromedical Evacuation (MEDEVAC)"; 1994 October 3-7; Athens, Greece: 3-1 – 3-7.
- Turner, M.A., Kiernan, M.D., McKechnie, A.G., Finch, P.J.C., McManus, F.B. and Neal, L.A., "Acute Military Psychiatric Casualties from the War in Iraq". British Journal of Psychiatry. 2005; 186: 476-479.
- Turner, S. and Ruth, M., "Critical Care Air Support Teams". In: Neilsen, J.N. (technical evaluator). NATO HFM-157. Proceedings of the Human Factors and Medicine Specialist Meeting on Medical Challenges in the Evacuation Chain. 2008; December 2-3; Seigburg; Germany. Available from: <http://ftp.rta.nato.int/public/PubFullText/RTO/MP/RTO-MP-HFM-157/MP-HFM-157-19.doc>.
- Turner, S., Ruth, M.J. and Bruce, D.L., "In Flight Catering: Feeding Critical Care Patients During Aeromedical Evacuation". JR Army Med Corps. 2008 December; 154(4): 282-283.
- United Kingdom National Institute of Health and Clinical Excellence, "Guideline 56 Head Injury". 26 September 2007.
- United Kingdom. Ministry of Defence. Clinical Guidelines for Operations: Joint Doctrine Publication 4-03.1 Change 2; Doctrine Concepts and Development Centre; February 2011.
- United States Department of Defence. "Emergency War Surgery – Third United States Revision". Washington, D.C., 2004.

## REFERENCES

---

Venticinque, S.G. and Grathwohl, K.W., “Critical Care in the Austere Environment: Providing Exceptional Care in Unusual Places”. Crit Care Med. 2008; 36(7(Suppl.)):S284-S292.

Walton, C.S., “Aeromedical Evacuation (AE) From Afghanistan of a Patient with Serious Lung Injury Using The Acute Lung Rescue Team”. Paper presented at: the 81st Annual Scientific Meeting of the Aerospace Medical Association; 2011 May 9-13; Phoenix, Arizona, USA. Available at: [http://www.asma.org/asma2010\\_mp/pdfs/asma2010\\_present\\_163.pdf](http://www.asma.org/asma2010_mp/pdfs/asma2010_present_163.pdf).

Wivell, P. (producer), “Cutting Edge – The Air Hospital” [TV episode]. London: IWC Media, Channel 4; 2010 March 25.

### 11.3 CONCEPT/DOCTRINAL DOCUMENTS

General Dynamics Information Technology, “Future Modular Force Resupply Mission for Unmanned Aircraft Systems (UAS), Prepared for CG Combined Arms Support Command and Department of the Army, G-4”. Fairfax, Virginia. 24 February 2010.

NATO Joint Air Power Competence Center, “Strategic Concept of Employment for Unmanned Aircraft Systems in NATO”. 4 January 2010.

United Kingdom Ministry of Defence, “Joint Doctrine Note 2/11 – The UK Approach to Unmanned Aircraft Systems”. 30 March 2011.

United States Army UAS Center of Excellence, “Eyes of the Army – U.S. Army Roadmap for UAS Operations 2010-2035”. Fort Rucker, Alabama. 14 January 2010.

United States Department of Defense, “Chairman Joint Chiefs of Staff Instruction – CJCSI 3255.01 – Joint Unmanned Aircraft Systems Minimum Training Standards”. 17 July 2009.

United States Department of Defense, DoD Instruction (DoDI) 5000.02, “Operation of the Defense Acquisition System”. 8 December 2008.

United States Department of Defense, “DoD Unmanned Systems Roadmap – 2007-2032”. 10 December 2007.

United States Department of Defense, “Joint Concept of Operations for Unmanned Aircraft Systems”. November 2008.

United States Joint Forces Command, “Unmanned Aerial System Casualty Evacuation Concept of Operations and Safe Ride Standards”, Draft. 16 August 2010.

United States Marine Corps Combat Development Command, “Concept of Operations for United States Marine Corps Unmanned Aircraft Systems Family of Systems”. October 2009.

USMC Warfighting Laboratory, Memo: MCWL Interest in Robotic and Unmanned Systems Research. 15 April 2008.

USMC Warfighting Laboratory, “Enhanced Company Operations Limited Objective Experiment 3.3 Final Report”, 11 August 2009.

United States Air Force, “Air Force Instruction (AFI) 10-601 – Operational Capability Requirements Development”. 12 July 2010.

United States Army, “FM 4-02.2 – Medical Evacuation”. 8 May 2007.

United States Army, “FM 4-02.4 – Medical Platoon Leader’s Handbook”. 24 August 2001.

United States Army, “FM 8-10-6 – Medical Evacuation in a Theatre of Operations”, 14 April 2000.

United States Army, “*Initial Capabilities Document (ICD) for Unmanned Systems (Air, Ground, Maritime)*”, 14 May 2010.

United States Army Training and Doctrine Command, “TRADOC Pamphlet 525-66, Force Operating Capabilities”, 7 March 2008.

United States Army Training and Doctrine Command, “TRADOC Pamphlet 525-7-15, The United States Army Concept Capability Plan for Army Aviation Operations 2015-2024”, 12 September 2008.

United States Congressional Budget Office, “Policy Options for Unmanned Aircraft Systems”. June 2011.

United States Department of Defence, “FY2009 – 2034 DOD Integrated Unmanned Systems Roadmap”, 6 April 2009.

## **11.4 ENGINEERING REFERENCES/STANDARDS**

American Society for Testing and Materials (ASTM), ASTM F2318 – 04 Standard Specification for Rotary Wing Basic Life Support, Advanced Life Support, and Specialised Medical Support Air Ambulances. 1 April 2004.

American Society for Testing and Materials (ASTM), ASTM F2319 – 04 Standard Specification for Fixed Wing Basic Life Support, Advanced Life Support, and Specialised Medical Support Air Ambulances. 1 April 2004.

CEN (Committee European Normalisation / European Committee for Standardisation), EN 137181: 2008 Medical Vehicles and Their Equipment – Air Ambulances – Part 1: Requirements for Medical Devices Used in Air Ambulances. 2008.

CEN (Committee European Normalisation/European Committee for Standardisation), EN 13718-2:2008 Medical Vehicles and Their Equipment – Air Ambulances – Part 2: Operational and Technical Requirements of Air Ambulances. 2008.

CEN (Committee European Normalisation/European Committee for Standardisation), CEN 1789 “Medical Vehicles and Their Equipment 1”. 29 June 2007.

Defence Technical Information Center, “Directory of Design Support Methods”. August 2007.

European Aviation Safety Agency, “Certification Specifications for Small Rotorcraft – CS-27”. 17 November 2008.



## REFERENCES

---

Georgia Tech Research Institute and Georgia Institute of Technology, “HSI Expeditionary Medical Design Tool”, as found at <http://hsimed.gtri.gatech.edu/home.php>.

Human Factors Engineering Technical Advisory Group, “Human Engineering Design Data Digest”. April 2000.

Human Factors Engineering Technical Advisory Group, “Index of Government Standards on Human Engineering Design Criteria, Processes, and Procedures”, 1 November 2004.

Human Factors Engineering Technical Advisory Group. “Index of Non-Government Standards on Human Engineering Design Criteria and Program Requirements/Guidelines”, 1 October 2002.

IEEE, “IEEE Std C95.1 – IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields”. 8 December 1998.

National Aeronautics and Space Administration, “NPR 8705.2B – Human-Rating Requirements for Space Systems”, 6 May 2008.

United Kingdom, “Statutory Instruments 2005 No, 1093 – “The Control of Vibration at Work Regulations 2005”. 6 July 2005.

United Kingdom Ministry of Defence, “Defence Standard 00-250 – Human Factors for Designers of Systems”. 23 May 2008.

United States Air Force, Air Force Instruction (AFI) 10-601 “Air Force Requirements Generation Process and Procedures”. Attachment 1. 12 July 2010.

United States Department of Defense, “The Defense Acquisition Guidebook (DAG)”. August 2010.

United States Department of Defense, “MIL-HDBK-310 – Global Climatic Data for Developing Military Products”. 9 January 1987.

United States Department of Defense, “MIL-HDBK-516B – Airworthiness Certification Criteria”. 26 September 2005.

United States Department of Defense, “MIL-HDBK-759C – Handbook for Human Engineering Design Guidelines”. 31 July 1995.

United States Department of Defense, “MIL-HDBK-1908B – Definitions of Human Factors Terms”. 16 August 1999.

United States Department of Defense, “MIL- STD-810 – Environmental Engineering Considerations and Laboratory Tests”. 1 January 2000.

United States Department of Defense, “MIL-STD-882D – Standard Practice for System Safety”. 19 January 1993.

United States Department of Defense, “MIL-STD- 1472F – Design Criteria Standard Human Engineering”. 5 December 2003.

United States Department of Defense, “MIL-STD-1474D – Noise Limits”. 12 February 1997.

United States Department of Defense. “Department Of Defence Instruction (DoDI) 5000.02 “Operation of the Defense Acquisition System”. 8 December 2008.

United States Department of Defense, “Mil-HDBK 46855A – Human Engineering Program Process and Procedures”. 2002.

United States Federal Aviation Administration, “DOT/FAA/CT-03/05 HF-STD-001 Human Factors Design Standard”. May 2003.

## 11.5 MISCELLANEOUS

Beebe, M. and Gilbert, G., “Robotics and Unmanned Systems – ‘Game Changers’ for Combat Medical Missions”. Paper presented at NATO Use of Advanced Technology and New Procedures in the Medical Field Symposium and Published in RTO-MP-HFM-182. NATO RTO Paris April 2010.

Conant, T. (BG) USMC, Director, Expeditionary Force Development Center, Marine Corps Combat Development Command, ltr to Dr. A. Tether, Director, DARPA, “*Nightingale MedEvac UAV Project Interest*”, dated 31 May 2005.

Concise Oxford English Dictionary. 11<sup>th</sup> Ed. Oxford: Oxford University Press, 2006.

Congressional Research Service. “*U.S. Unmanned Aerial Systems*”. Washington, D.C., 2 January 2012.

De Mooij, C., “De Toepassing Van Onzichtbare Lichtsralen Om Actereenvolgens Dedeelten Van Het Slagveld Te Verlichten Zonder Door Den Vijand Te Worden Gezien”, *De Ingenieur* (Netherlands) 1912, #38: 768-769.

De Mooy, C., “Over Het Vervoer Van Lijders In De Toekomst, Met Bestuurbare Ballons En Aeroplanen”, *De Sirene* (Netherlands) # 8, 17 December 1910: 95-98.

De Mullinen, F., “Handbook on the Law of War for Armed Forces”. International Committee of the Red Cross, Geneva, Switzerland. 1987.

Edmonson, A., Bohmer, R. and Pisano, G., “Speeding Up Team Learning”. *Harvard Business Review*, October 2001, 125-132.

Greenbank, C. and Ayliffe, A., “Assessing Human Factors in UK Military UAVs”, NATO RTO Technical Report MP-SCI-162-05B, May 2005.

Griffith, P., “Casualty Evacuation Helicopters: Re-Evaluating the Role of the ‘DUSTOFF’ in the Vietnam War”. Undated, but Retrieved December 30, 2008, from <http://www.historynet.com/casualty-evacuation-helicopters-re-evaluating-therole-of-the-dustoff-in-the-vietnam-war.htm>.

Goulding, V. Jr., Director, Experimentation Division, Marine Corps Warfighting Laboratory ltr to CG, U.S. Army Medical Research and Materiel Command Telemedicine and Advanced Technology Research Center, “*MCWL Interest In Robotic And Unmanned Systems Research*”, dated 15 April 2008.

## REFERENCES

---

Hill, M., Konoske, P., Galarneau, M. and Pang, G., “Marine Corps CASEVAC: Determining Medical Supply Requirements for Long-Range Casualty Evacuation Aircraft”. Naval Health Research Center, Report No. 03 – 20 August 2003.

Hirschberg, M.J., “To Boldly Go Where No Unmanned Aircraft Has Gone Before: A Half-Century of DARPA’s Contributions to Unmanned Aircraft”. AIAA 2010-158. January 2010.

ISAF, “Troop Contributing Nations” [internet] 2011 October 18 [cited 2011 December 10]. Available from: <http://www.isaf.nato.int/images/media/PDFs/18%20october%202011%20isaf%20placemat.pdf>.

John Hopkins/Applied Physics Laboratory CBRN Payload and Operator Training Class After Action Report for Demo #9, April 2010.

Jones, C.A., “Unmanned Aerial Vehicles (UAVs) – An Assessment of Historical Operations and Future Possibilities”. USAF Air Command and Staff College, March 1997.

Lam, D.M., “To Pop a Balloon: Aeromedical Evacuation in the 1870 Siege of Paris”, *Aviation, Space, and Environmental Medicine* 1988; 59 (10):988-991.

Lum, M.J., Rosen, J., King, H., Friedman, D.C., Donlin, G., Sankaranarayanan, G., Harnett, B., Huffman, L., Doarn, C., Broderick, T. and Hannaford, B., “Telesurgery via Unmanned Aerial Vehicle (UAV) with a Field Deployable Surgical Robot”. *Studies in Health Technology and Informatics*. 2007;125:313-315.

McCarley, J.S. and Wickens, C.D., “Human Factors Implications of UAVs in the National Airspace”. Technical Report AHFD-05-05/FAA-05-1. Savoy, IL: University of Illinois, Aviation Human Factors Division. 2005.

United Kingdom Ministry of Defence, “Joint Doctrine Note 3/10 – Unmanned Aircraft Systems: Terminology, Definitions and Classification”. May 2010.

USAMRMC, “TATRC SBIR Unmanned Ground and Air System for CBRN Contaminated Personnel Recovery (SBIR A08-121)” Solicitation, May – June 2008.

US Army AMEDD Center and School, “Memorandum: Feasibility of Using Unmanned Aircraft System for Potential Robotic CASEVAC”. 20 November 2009.

US Army AMEDD Center and School – “Memorandum: Directorate of Combat and Doctrine Development’s Position on Use of Unmanned Aerial Vehicles (UAV) for Patient Movement”. 20 January 2010.

US Army, “Unmanned Systems Initial Capabilities Document for Unmanned Systems (Air, Ground, and Maritime)”. December 2009.

US Army, “The United States Army Concept Capability Plan for Army Aviation Operations 2015-2024 (TRADOC Pamphlet 525-7-15)”, 12 September 2008.

USMC, Concept of Operations for United States Marine Corps Unmanned Aircraft Systems Family of Systems, Version 2.0, 10 November 2009.

USMC Warfighting Laboratory, Statement of Work, “*Immediate Air Cargo Unmanned Aerial System*”, 24 March 2009.

USSOCOM Special Operations Forces Long Endurance Demonstrator (SLED) Advanced Capability Technology Demonstration, FY 2007.

Vandre, R.H., Klebers, J., Tesche, F.M. and Blanchard, J.P., “Minimizing the Effects of Electromagnetic Pulse (EMP) on Field Medical Equipment” (ECD No. 5043629). Washington, DC: U.S. Army Institute of Dental Research. 1991.

Warwick, G., “Army Eyes Unmanned Aircraft for Casualty Extraction”. Aviation Week, 14 October 2010. Online at: <http://www.aviationweek.com/aw/blogs/defense/index.jsp?plckController=Blog&plckScript=blogScript&plckElementId=blogDest&plckBlogPage=BlogViewPost&plckPostId=Blog:27ec4a53-dcc8-42d0-bd3a-01329aef79a7Post:d31069fe-39a9-45d0-bc53-56226a0b4418>.

## **11.6 NATO DOCUMENTS**

AJMEDP-2, “Allied Joint Doctrine for Medical Evacuation”, Ed 1, 24 November 2008.

AMEDP-11 (A), “NATO Handbook on Maritime Medicine”, November 2008.

AMEDP-38, “Medical Aspects in the Management of a Major Incident/Mass Casualty Situation”, Final Draft July 2011.

AJP-4.10 (A), “Allied Medical Support Doctrine”, 3 March 2006.

ATP-3.3.7 – “Recommended Guidance for the Training of Unmanned Aircraft Systems (UAS) Operators”, Ratification Draft 2011.

ATP-10 (D) – “Search And Rescue”, 1 January 1995.

COMEDS (LO)L(2010)0004 “Report from COMEDS on the Long Term Capability Requirements”, 17 March 2010.

Joint Capability Group Unmanned Aircraft Systems (JCGUAS), “Programme of Work”, PFP(NNAG-JCGUAS)D(2012)0002, 2012.

Joint Unmanned Aircraft Systems Working Group (JUASWG). “Draft Terms of Reference”, November 2010.

MC 0601 – “NATO Airworthiness Policy”, 27 September 2011.

MC 326-3 – “NATO Principles and Policies of Medical Support”, 26 September 2011.

STANAG 2040 (Ed 6) – “Stretchers, Bearing Brackets, and Attachment Supports”. 6 October 2004.

STANAG 2087 (Ed 6) – “Medical Employment of Air Transport in the Forward Area”, 30 October 2008.

STANAG 2289 – “Doctrine and Procedures for Tactical Unmanned Aerial Vehicles in Land Operations”. SD 1, 2010.

## REFERENCES

---

STANAG 2342 – “Minimal Essential Medical Equipment and Supplies for Military Ambulances at all Levels”. 18 February 2005.

STANAG 2872 (Ed 3) – “Medical Design Requirements for Military Motor Ambulances”, 3 April 1989.

STANAG 2931 (Ed 2) – “Orders for the Camouflage of the Red Cross and the Red Crescent on Land in Tactical Operations”, 19 January 1998.

STANAG 3204 (Ed 7) – “Aeromedical Evacuation”, 1 March 2007.

STANAG 3950 – “Helicopter Design Criteria for Crew Crash Protection and Anthropomorphic Accommodation”, Ed 2, 14 February 2001.

STANAG 4586 – “Standard Interfaces of UAV Control Systems (UCS) for NATO UAV Interoperability”, Ed 3, RD 1, March 2010.

STANAG 4670 – “Recommended Guidance for the Training of Designated Unmanned Aerial Vehicle Operators”, Ed 1, 28 April 2009, and SD Ed 2.

STANAG 4671 – “UAV System Airworthiness Requirements”, Ed 1, 3 September 2009.

## 11.7 STATUS OF DEVELOPMENT OF UAS

Dillard, J.T., “From Amorphous to Defined: Balancing Risks in Evolutionary Acquisition”. Defence Acquisition University. 2009.

Hacunda, J., (Dragonfly Pictures, Inc.), “UAV – Combat Medic Collaboration for Re-Supply and Evacuation”. Program Review 15 January 2010.

Homeland Security Newswire, “Flying Ambulance: UAV will Extract Wounded Soldiers from the Battlefield”. <http://www.homelandsecuritynewswire.com/flying-ambulance-uav-will-extract-wounded-soldiers-battlefield?page=0,1>. 12 March 2010.

Gilbert, G. and Beebe, M., “United States Department of Defense Research in Robotic Unmanned Systems for Combat Casualty Care”. Paper presented at NATO Use of Advanced Technology and New Procedures in the Medical Field Symposium and published in RTO- MP-HFM-182. NATO RTO Paris April 2010.

Katz, Y., “IDF Plans Pilotless Chopper to Evacuate Wounded”. Jerusalem Post. 1 July 2011.

Robson, S., “Navy Agrees to Buy 4 Unmanned Helos”. Stars and Stripes. 15 January 2011: 5.

Tuttle, R., “AUVSI: Transformers: Robots in disguise”. Flight Daily News, 25 August 2010.

United States Federal Aviation Administration, “Fact Sheet – Unmanned Aircraft Systems (UAS)”. 10 June 2010.

UVS News Flash, “Unmanned Aircraft Systems”. Issue 2009/11, 30 June 2009.

Warwick, G., "Unconventional Lift", Aviation Week, 22 March 2010: 26-27.

Warwick, G., "Unmanned Helo Picks Best Place To Land". Aviation Week, 13 July 2010. Online at: [http://www.aviationweek.com/aw/blogs/aviation\\_week/on\\_space\\_and\\_technology/index.jsp?plckController=Blog&plckScript=blogScript&plckElementId=blogDest&plckBlogPage=BlogViewPost&plckPostId=Blog:a68cb417-3364-4fbf-a9dd-4feda680ec9cPost:3d66ce6a-1be8-4ce2-94a4-5e1d5149e6e1](http://www.aviationweek.com/aw/blogs/aviation_week/on_space_and_technology/index.jsp?plckController=Blog&plckScript=blogScript&plckElementId=blogDest&plckBlogPage=BlogViewPost&plckPostId=Blog:a68cb417-3364-4fbf-a9dd-4feda680ec9cPost:3d66ce6a-1be8-4ce2-94a4-5e1d5149e6e1).

Wilson, J.R., "Devil Droids/ UAVs and UGVs are Becoming Key Assets on the Battlefield". Marine Corps Outlook: 2010-2011 Edition.

## REFERENCES

---





## Annex A – TECHNICAL ACTIVITY DESCRIPTION



UNCLASSIFIED / UNLIMITED



### Technical Activity Description (TAD)

Activity reference number	HFM-184	Activity Title	Approval 2009
Type and serial number	RTG	Safe Ride Standards for patient Evacuation Using Unmanned Aerial Vehicles (UAVs)	Start August 2009 IS
Location(s) and Dates	1st Mtg: ATACC, St Pete, FL, (USA) 13-14 August 2009		End August 2012
Coordination with other bodies	COMEDS		
NATO Classification of activity	UU		Non NATO Invited Yes
Publication Data	TR		UU
Keywords	Aeromedical Evacuation, Unmanned Aerial Vehicles (UAV), Casualty Care, G-Tolerance, Casualty Aeromedical Assessment, Standardisation, Operational Aviation Medicine, Clinical Decision Making		

#### I. Background and Justification (Relevance to NATO):

Aeromedical evacuation has been carried on routinely in both fixed and rotary wing environments since the 1920s. The "G-force" flight parameters of these aircraft are controlled by on-board pilots, and thus are usually well within the tolerance limits of patients with varying degrees of disability/injury. However, there does not appear to be any internationally recognised set of "G-force" standards for casualties which can be used in development of flight profiles for Unmanned Aerial Vehicles (UAVs)—this is of special concern since UAVs have the ability to pull G-forces far in excess of any aircraft other than fighters. If UAVs are to be used in a patient evacuation role, it is necessary to have an agreed set of G-tolerance standards for patients which can be incorporated into the Artificial Intelligence Flight Controllers. Potential use of these vehicles for this purpose will likely be far-forward, and will involve the transport of freshly wounded, unstable, patients, who may be more susceptible to G-forces than would be stabilised patients.

#### II. Objective(s):

This activity will attempt to develop an evidence-based reference resource which can be used by UAV developers to ensure that the Artificial Intelligence programs used to control (more than piloting, also control environments, C2, etc.) UAVs will be able to support the use of these airframes in the casualty evacuation role. Absolute G tolerances of casualties with various injuries will be investigated, as will rate of G-onset. The majority of this work will be done through literature search and coordination with regulatory/scientific agencies.

#### III. Topic To Be Covered:

1. Development and Flight Characteristics of UAVs (current, planned and projected).
2. Control Mechanisms for UAVs, including remotely piloted (RPV) and controlled by on-board programming (Artificial Intelligence)
3. The potential use of UAVs for casualty evacuation.
4. G-tolerance and rate-of-onset tolerance of patients in various axes and with differing medical conditions.
5. In-flight medical monitoring

#### IV. Deliverable (e.g. S/W Engage Model, Database,...) and/or end product (e.g. Final Report):

Technical Report, other deliverable(s) : none

#### V. Technical Team Leader And Lead Nation:

Chair : BGen (Rtd) Erich ROEDIG Germany

Lead Nation: Germany

#### VI. Nations Really Participating:

Germany, Israel, United Kingdom, United States

#### VII. National And/Or NATO Resources Needed (Physical and non-physical Assets):

Individual nations resources will be required to support team members travel and participation in RTG meetings.

#### VIII. RTA Resources Needed:

Funding for consultants. Engagement of RTA liaisons including those to COMEDS.



## **Annex B – HISTORY AND DEVELOPMENT OF AERIAL EVACUATION, WITH SPECIFIC REFERENCE TO UAV POTENTIAL USE**

### **B.1 INTRODUCTION**

The methods used to evacuate casualties from the battlefield have evolved throughout the centuries. Every draft animal ever used by an Army has been pressed into evacuation service, as has nearly every type of vehicle. As each new vehicle has become generally available, it has been adapted to medical use. Horse-drawn wagons were gradually replaced by boats, trains and motor vehicles, which have since been supplemented by aircraft. Until well after WWI, however, one thing was sorely lacking in most aircraft used for this purpose – routine medical care en route. Gradually, throughout WWII and until our era, care en route has improved, patient survival has increased, and the logistics burden on the forward commander has been reduced through his improved ability to move casualties rearward rather than medical support forward.

During and since the Second World War, there has been increased emphasis on using evacuation to actually benefit the patient during transport, rather than seeing it simply as another form of “cargo hauling”. This requires specialised equipment and trained transport personnel. We see this development today primarily in some well-equipped ground vehicles and in some aircraft. However, it is well recognised in doctrine that in a large war, it is unlikely that any Nation can afford to provide every casualty with modern intensive-care level care during transportation, and in such circumstances we will probably fall back on less medically capable transport means, including casualty movement on vehicles of opportunity without any care en-route. However, in peace-keeping or crisis response operations, in which fewer casualties are expected, our Nations may demand that each and every patient receives the highest possible level of care. This demand is now NATO policy, in that MC 326/3 demands that the goal of NATO medicine is “to achieve outcomes of medical care equating to best medical practice”<sup>1</sup>, even in times of conflict. This demand on the part of our Nations will mandate ever-increasing reliance upon state-of-the-art evacuation capabilities for the foreseeable future. Unfortunately, there will always be a conflict between the demand for “peacetime/home country level of care” versus the practicalities of evacuation in a combat zone.

One of the most-used forms of patient transportation today is aircraft. The history and development of the capability move patients via air, and to provide in-flight medical care closely parallel both the history of flight itself and that of medical technology. From the earliest days of flight, physicians have been trying to use aircraft in the care of their patients, and it may be useful to review the development of this modality.

The history of aeromedical operations can be generally divided into four eras:

- Up to 1920, Including World War I – Theory and “heroic experiments”;
- 1920 – 1939, The Interwar Years – Intermittent interest and development of systems;
- 1940 – 1960, World War II, Korea, and Vietnam – Growth and development of systems – casualty as “cargo”; and
- 1961 – Present, Full acceptance, rapid growth, and increased use of advanced medical technology in flight – patient as “patient”.

---

<sup>1</sup> MC 326/3, Para 3.3.

## **B.2 EARLY HISTORY**

Although aeromedical evacuation has been most recently brought to public attention as a result of its massive use during the War in Vietnam and in more recent conflicts (including Iraq and Afghanistan), it is not a new concept. In fact, the concept of aeromedical transportation pre-dates even the first heavier-than-air powered flight by the Wright brothers in 1903. As early as March 1784, following the balloon flight demonstrations of the Montgolfier brothers before the medical faculty of Montpellier, physicians began to consider the benefits their patients could gain from flight. They early theorised that, not only could sick patients tolerate flight, but that they would in fact benefit from “the purer air encountered at altitude”. So far as can be determined, no practical use was ever made of the concept of balloon evacuation. It has been reported many times that in 1870, during the Prussian siege of Paris, over 160 sick and wounded patients were evacuated by means of balloons, but it can be stated with assurance that no such patient evacuations ever took place during the siege of Paris.<sup>2</sup>

Between 1892 and 1910, the innovative Surgeon General of the Dutch Army, General De Mooy, developed an entire concept for casualty evacuation, including ground vehicles, fixed-wing aircraft, dirigibles, and captive balloons pulled by horses<sup>3,4</sup>. His concept did not envision any care in flight, as it was assumed that casualty search and recovery was of more benefit to the casualty than would have been any type of limited in-flight care. Unfortunately, this forward-looking concept, which gained him the sobriquet of “the Jules Verne of aviation medicine”<sup>5</sup>, was never tested nor implemented.

The first practical effort in the development of the concept of aeromedical evacuation occurred in 1909, when Captain George Gossman, a U.S. Army medical officer, joined with Lieutenant Albert Rhodes of the Coast Artillery Corps in designing and building an aircraft specifically for the transportation of patients. The aircraft, though crude and requiring the patient to lie unprotected on the wing alongside the pilot, was successfully flown (once!); and Gossman and Rhodes attempted to convince the War Department to develop the concept further. Since this proposal was made only a year after the U.S. Army purchased its first motor-driven ground ambulance, and in the same year in which it purchased its first aircraft (it was not to purchase another for two years), it may be imagined with what degree of success they met. In the face of War Department obstinance, numerous medical officers took up the battle for air evacuation. The response of the War Department echoed that of the newspaper, the Baltimore Sun, which proclaimed that “the hazard of being severely wounded was sufficient without the additional hazard of transportation by airplane”. Issues of patient isolation in flight, and the inability to provide care during transportation were discussed, and used as arguments against the use of aircraft for this purpose.

## **B.3 WORLD WAR I – THE FIRST ATTEMPTS**

In France, too, military medical professionals faced opposition from the Ministry of War in attempting to develop an air evacuation capability, but the opposition of the conservatives was to be overridden by the force of circumstances. In November of 1915, during the retreat of the Serbian Army from Albania, it became impossible to evacuate all the sick and wounded of the French Expeditionary Force by ground means, and it was unthinkable to abandon the wounded to capture. Therefore, although the only available aircraft were

---

<sup>2</sup> Lam, D. “To Pop A Balloon: Aeromedical Evacuation in the 1870 Siege of Paris”.

<sup>3</sup> De Mooy, C. “Over Het Vervoer Van Lijders In De Toekomst, Met Bestuurbare Ballons En Aeroplanen”.

<sup>4</sup> De Mooij, C. “DeToepassing Van Onzichtbare Lichtsralen Om Actereenvolgens Dedeelten Van Het Slagveld Te Verlichten Zonder Door Den Vijand Te Worden Gezien”.

<sup>5</sup> Nijhoff, M. “Generaal De Mooy, De Jules Verne Van Den Gezondheids-Luchtdienst”.

fighter aircraft in poor condition, the decision was made to attempt evacuation by air through the placement of patients in the rear cockpits of fighter aircraft. The first heavier-than-air evacuation in history took place on 15 November 1915, and over the succeeding month, 13 wounded were evacuated from front-line, poorly-prepared airstrips, often within rifle shot of the enemy – the first use of aircraft for “CASEVAC”. Based on this dramatic evidence of the usefulness of aerial evacuation, as well as on the results of exercise trials, the French Government authorised the development of the first air ambulances, which were first used in combat on the Aisne front in 1917. However, the risk of aircraft losses derailed this experiment, with one member of the Chamber of Deputies crying “Are there not enough dead in France today without killing our wounded in airplanes?”

Interestingly, our RTG has heard from several sources objections to the use of UAVs in this context which are directly reminiscent of these initial arguments against the use of aircraft for patient transportation.

The United States, in gearing up for entry into WWI, developed numerous new flying fields. These fields were established in areas of the country with poor roads, and it was often a matter of several hours before a student pilot injured in a crash could be brought to a hospital. Flight Surgeons rapidly began to develop medical conversions of the JN-4 “Jenny” training aircraft, and by 1919 such ambulances were a fixture on all training fields, though none provided any capability for in-flight care. Most flights were from the scene of injury to the nearest point at which medical care could be provided.

By the end of WWI, air ambulances were in regular use in the United States and Canada, and had seen limited use in France. No other Nation actually used aircraft for evacuation, though the United Kingdom had experimented with it before the war. However, neither medical systems nor the airframes themselves were able to allow in-flight medical care. Though built in numerous versions, each of these early air ambulances had one common feature – the patient was enclosed in the fuselage, without an attendant, and with no possibility for care in flight. In this regard, they were the model for most air ambulances during this period. Even though the air ambulance was a reality, it was seen only as a means of transportation, rather than as an integrated part of the medical care system. Interestingly, deaths in flight, or adverse patient reactions to being enclosed in the coffin-like enclosures, are almost unheard of during this period.

### **B.4 INTERWAR USE**

Although air ambulances were certainly in increasing use following WWI, there did not appear to be any great need for systematic air evacuation on a large scale during peacetime. Most Nations paid little attention to the issue, though military air evacuation systems were developed by France and Britain for use in their colonial wars, and successfully used to evacuate thousands of casualties. For the first time, there was an effort to provide some limited in-flight care, and one French Breguet XIV-b Limousine was described as having “electric boilers, coverlets, tank of oxygen, surgical instruments, and dressings” (though generally this equipment was to be used on the ground, prior to flight). For the first time, aircraft were integrated into the military medical system, under the command of non-medical officers. The benefits were clearly recognised, but unfortunately the systemic changes needed in military medical establishments to make optimum use of this new modality were not adopted by most Nations. The French developed a “two-stage evacuation system”, in which casualties were removed from the battlefield to a position of safety or medical care on small aircraft with no capability for care en route, and then subsequently were moved a greater distance on larger and more capable aircraft, some of which allowed care to be delivered in flight.

Beginning in 1920, the U.S. Army developed an ambulance modification of the Dehavilland DH-4, which was produced in significant numbers, and several of which were used extensively on the Mexican border. Just as

had been the case with earlier air ambulances, these planes carried their patients isolated in coffin-like enclosures built into the fuselage. As these planes became obsolete, the U.S. Army began to experiment with various types of air ambulances, most of which were produced in only one copy for experimental purposes. Some of these, notably the Curtis Eagle, provided adequate space inside so that a physician could accompany the patient and could (at least theoretically) provide some care in flight. In 1930, the Ford Trimotor of the U.S. army was described as the “largest and most complete airplane ambulance ever designed”. It carried a physician and medical technician, who had access to various instruments, drugs, splints, and dressings. However, during the money-tight 1930s, the United States was unable to really create an air ambulance service, and official interest in the concept was nearly non-existent.

This interest on the part of medical professionals was not restricted only to the United States, France, and the United Kingdom. During the 1930s, most aircraft manufacturers in Europe produced at least one ambulance version, and soon there appeared ambulance versions of amphibians, flying boats, “touring airplanes”, and float planes, in addition to the normal military aircraft of the day. Both military and civilian versions were produced, with significant civilian use being made of them in countries with large, sparsely-populated, regions such as Sweden, Thailand, and Russia. The most comprehensive civil system was probably that of Russia, while France and Germany developed probably the world’s most extensive military systems prior to WWII, with France even fielding squadrons of small aircraft with built-in patient oxygen (though they still could provide no other in-flight care capability). The Germans developed an extensive system of evacuation during the Spanish Civil War, by which casualties from the German Condor Legion were evacuated over the Alps, covering distances of up to 1600 miles at altitudes of up to 18,000 feet in unpressurized JU-52 aircraft. Only minimal care beyond oxygen and dressing changes was available in-flight.

## **B.5 WORLD WAR II – MASS EVACUATIONS AND IMPROVED CARE IN FLIGHT**

During WWII, necessity dictated the development of a world-wide air evacuation policy for both sides. The Germans had an extensive military evacuation system established at the time of the onset of war with Poland, and by August of 1941 they had evacuated over 280,000 casualties. The Russians used air ambulances extensively during the Winter War with Finland, though again only minimal care en route was possible – their larger aircraft carried only Oxygen as a treatment modality, along with hot water bottles and blankets. Some of their evacuations were even more basic, reverting to the concepts of patients as cargo – they actually carried patients in enclosed pods mounted on, or hanging under, the wings of their PO-2 and U-2 aircraft. Again, it must be noted that adverse effects on patients or their conditions were not reported. However, the massive distances involved in this war rapidly led to a heavy reliance on aerial evacuation in all theatres. From the time of the early Japanese successes in Southeast Asia to the end of the war, over 1.2 million patients were evacuated by U.S. aircraft alone, utilising standard cargo aircraft, usually without medical support. Patients were not restricted by injury type, and in fact all types of casualties were moved. Care in flight continued to be developed, and by the middle of the war this capability included injections, transfusions, pleural fluid or air aspirations, and tracheal care, provided by trained Flight Nurses. Long-range aeromedical evacuation had become a reality.

Ad hoc innovation was common. One prime example of the innovations developed in the realm of air evacuation took place in June 1944 when an officer in Western China developed Respiratory Polio. He survived 14 days of artificial ventilation, while an airstrip was built. A homemade respirator was designed, and he was flown out in a small aircraft, with the patient himself powering the chest compression pump as he rode. Subsequently, he was flown “over the hump” to India in a C-47 with an iron lung.



Although the major form of air evacuation during WWII was long range, what we now call theatre or strategic, it must be realised that another form of air evacuation was also in use, which is more directly relevant to our consideration of UAVs in the field of evacuation. While there were continuing efforts to improve the amount and quality of care which could be given in flight during the long-range flights, there was a realisation that other flights from the forward areas to medical facilities to the rear were still needed, even if care in flight was not available. Accordingly, small aircraft were routinely used on a regular basis by all the belligerents, and helicopters began their career as lifesavers, though on a very limited basis.

### B.6 CONTINUED DEVELOPMENTS POST-WWII

First used to evacuate casualties from isolated patrols and airplane crashes in Burma, the helicopters soon developed a reputation as lifesavers, and new models were rapidly developed. Used by the French in Indochina after WWII, by the British in Malaysia, and by the U.S. and allied forces in Korea, helicopters rapidly took over the role of short-range evacuation from the small fixed wing aircraft. Although only very limited care was available in flight (IVs including plasma, inserted prior to flight), the helicopter became a mainstay of military medical services.

Continued development was the norm after the Korean War. For example, in 1954, the U.S. C-131 was produced in series, the first specifically-designed fixed wing air ambulance with modern technology. It was not only pressurised, but air conditioned, and was designed to routinely carry major medical life support equipment such as iron lungs.

Looking back, we are forced to observe that the record of air evacuation in WWII and the Korean War, though a proud one, is not the product of such imagination, development, and forward planning as one expects of the air age. The most persistent experimenter was “necessity”, faithfully providing again and again situations in which air was the only or the best means of evacuation. It can appropriately be assumed that “necessity” rather than “doctrine” will be the most likely impetus for the first use of UAVs for this purpose.

The shortcomings of the early helicopters were recognised as a result of their use in Indochina, Malaysia, and Korea, and soon after the Korean War a design competition was held to choose a new U.S. Army helicopter ambulance. The winner of the competition, the Bell XH-40, later to be called the HU1 “Huey”, was built to medical department specifications, and became the most successful helicopter ambulance of its era. With the development of the Huey, along with organisational and operational changes made between the wars, the U.S. Army was well-prepared to carry out forward air evacuation missions during the War in Vietnam. For the first time in the history of warfare, there was an extremely good chance that a soldier wounded in battle could be receiving specialised medical care within one to two hours of being wounded. Specially trained medical corpsmen were employed on these aircraft, and contributed greatly to the success of the mission, starting IVs, stopping bleeding, maintaining airways, and occasionally even doing life-saving surgery such as cricothyroidotomies. As a result, of those evacuated who lived to reach a medical facility, about 98% survived, hospital stays were reduced, and the overall risk of dying in combat if wounded was reduced to less than ½ of the risk during WWII. At the same time that the Army was carrying out its forward mission of air evacuation, the U.S. Air Force re-activated its massive inter-theatre airlift of WWII and Korea, moving hundreds of thousands of troops out of Southeast Asia to Japan, the Philippines, and to the United States. Of great importance was the inclusion on the crews of flight nurses and medical technicians who were able to carry out increased levels of medical care and monitoring in flight.

Since the Vietnam War, there has been continuous improvement in the medical capabilities found on air ambulances. In the late 1960s, aircraft routinely carried stryker frames and respirators. Emerson plural



drainage pumps and closed water seal drainage became the norm. Intermittent positive pressure breathing devices were flown routinely, as were the then-new Baby Bird Respirators. In the 1970s, air ambulances began to routinely carry neonatal transport units, physiologic monitoring equipment, defibrillators, and IV pumps. By 1973, Belgium had Aerospatiale Pumas with sophisticated medical equipment for intubation, suction, drainage, probing, cardiac infarction monitoring, defibrillation, etc. In the 1980s, it became nearly routine to fly with Intraaortic balloon pumps and Doppler blood pressure measuring devices, especially in the civil sector. Portable hyperbaric chambers have been routinely flown since the late 1980s. This rapid infusion of medical technology into the air environment does not show any sign of slowing down. There is now only a lag time of 4 – 5 years between introduction of a piece of equipment into the hospitals before it appears in the air, and that appears to be decreasing. Today, almost any piece of medical equipment short of an MRI has been put into an aircraft, and we have finally reached the capability of the true flying Intensive Care Unit. But, it appears that such a capability may not be fully usable in all phases of operational missions.

*... and today, 100 years after its inception, casualty evacuation and movement – both intra- and inter-theater – by aircraft is the preferred method of transport.*

## **B.7 CURRENT PERIOD, AND THE RELEVANCE OF UAVs TO FUTURE EVACUATION OPERATIONS**

Current operations, including those in ISAF, seem to require new concepts of evacuation. The risk to air ambulances is so high in Afghanistan that American MEDEVAC aircraft are often not allowed to launch on missions without accompanying gunships. Delays in evacuation due to the unwillingness of command to risk air ambulances without gunship support have been widely reported in the press. The Israelis, following the last Lebanon incursion, have spoken forcefully about the need for smaller, more agile evacuation platforms which can evacuate casualties from the scene of injury, often in a zone too hazardous or too small for manned aircraft, not necessarily to a fully-equipped hospital, but simply to a safe area where they can be provided care and perhaps be transferred to a fully-equipped air ambulance.

Given the projected imminent arrival on the battlefield of UAVs capable of carrying casualties (even though neither designed nor purchased for that purpose), it appears that we are about to start a new cycle of development. However, just as the development of the helicopter ambulance has not totally replaced the ground vehicle used as an ambulance, it appears unlikely that the UAV can, or should, replace the airplane or helicopter ambulance. However, its use as a transport of opportunity to supplement actual air ambulances seems almost a given. It seems fascinating that the majority of the arguments against the use of UAVs for this purpose are exactly the same as were used to argue against both FW and RW evacuation in the early days of development of these modalities. We predict that, like it or not, such use of UAVs is going to happen in the near future, probably as a result of “field expediency” – the exact same process as that which led to our current state of the art in aeromedical evacuation. CASEVAC operations appear to be the most likely to appear in the short-term, with true MEDEVAC use of UAVs not being feasible until both UAVs and portable medical equipment for use in-flight undergo significant improvement.

The guiding principle must be, as always in military medicine, to develop mechanisms for using new concepts and equipment for the benefit of the patient. This development cannot be done in a vacuum, and must always be guided by the principle of “primum non nocere”, or “First of all, do no harm”.

## **Annex C – AN ABBREVIATED HSI ANALYSIS REGARDING THE UTILIZATION OF UAVs FOR CASUALTY TRANSPORTATION<sup>1</sup>**

NOTE: Due to space constraints, only a limited HSI analysis will be presented in this document. Rather than review each Domain interdependency, summary statements will be made for each Domain. It must be noted that much of this discussion will apply only to UAVs specifically being designed for CASEVAC or MEDEVAC use, while other discussion will apply in general to any UAV which may be considered for such use.

### **C.1 GENERAL OVERVIEW OF HSI**

HSI is the integrated and comprehensive analysis, design and assessment *of* capability requirements, concepts and resources *for* system manpower, personnel, training, environment, safety, occupational health, habitability, survivability, and human factors engineering, with the aim *to* reduce total ownership cost, while optimizing total mission performance. This integrated and comprehensive process is both iterative and recursive in addition to being pre-emptive in its assessments. As a performance process, it must be well aware of the complex dynamics resulting from the varied range of military operations within the context of the socio-geo-political operational constraint framework.<sup>2,3</sup>

The goals of HSI are to ensure that systems, equipment, and facilities:<sup>4</sup>

- Achieve the requisite usability by incorporating effective human-system interfaces.
- Achieve the required levels of human performance.
- Make economical demands upon personnel resources, skills, and training.
- Minimize life cycle costs.
- Manage risk of loss or injury to personnel, equipment, or environment.

The above goals of HSI are reflected in condensed form within DoD policy for the Defense Acquisition System<sup>5</sup>:

- Optimize total system performance;
- Enhance capability or system sustainability; and
- This minimizes total ownership costs by ensuring that the system is built to accommodate the characteristics of the user population that will operate, maintain, and support the system.

---

<sup>1</sup> Adapted directly from the Georgia Tech Research Institute and Georgia Institute of Technology “HSI Expeditionary Medical Design Tool”.

<sup>2</sup> Source: AFI 10-601, Attachment 1 (12 July 2010).

<sup>3</sup> Folds, D.J. and Martindale, V.E. (2010). “Human systems integration in expeditionary medical treatment facilities”.

<sup>4</sup> Source: MIL-HDBK-46855A 5.1.2.2.

<sup>5</sup> DoDI 5000.02.

The following four concepts are apparent, derived from the definition:

- HIS, which is an iterative and recursive process, is both integrated and comprehensive technical work. HSI technical work spans across (i.e. integrates) the human elements of Systems Engineering with comprehensive analysis, design, and assessment.
- The technical work done by HSI is applied to the systems engineering processes associated with capability requirements and concepts, as well as people, equipment, workspaces and facilities (resources).
- HSI provides a technical strategy for managing the technical work associated with all of the human-related concerns of systems engineering.
- HSI provides a management strategy for controlling total ownership cost while optimizing mission performance.

## **C.2 OVERVIEW OF THE TECHNICAL APPLICATION OF HUMAN SYSTEMS INTEGRATION (HSI)**

### **C.2.1 Analysis**

Starting with a mission analysis developed from a baseline scenario that explicitly stipulates the operational environmental constraints, the functions that must be performed by the system in achieving its mission objectives should be identified and described. These functions should be analyzed to determine their best allocation to personnel, equipment, software, or combinations thereof.

Allocated functions should be further decomposed to define the specific tasks that must be performed to accomplish the functions. Each task should be analyzed to determine the human performance parameters; the system, equipment, and software capabilities; and the tactical/environmental conditions under which the tasks will be conducted.<sup>6</sup>

Task parameters should be quantified where possible, and should be expressed in a form that permits effectiveness studies of the human-system interfaces in relation to the total system operation. High-risk areas should be identified as part of the analysis. Analyses should be iterative, and updated as required to remain current with the design effort.<sup>7</sup>

### **C.2.2 Design and Development**

HSI should be applied to the design and development of the system equipment, software, procedures, work environments, and facilities associated with the system functions requiring personnel interaction.

This effort should convert the mission, system, and task analysis data into detail design and development plans to create a system that will operate within human performance capabilities, meet system functional capability requirements, and accomplish mission objectives.<sup>8</sup>

---

<sup>6</sup> Additional source MIL-STD 1472F 4.3-4.4.

<sup>7</sup> Source: MIL-HDBK-46855A 4.1.1.1.

<sup>8</sup> Source: MIL-HDBK-46855A 4.1.1.2.

### C.2.3 Test and Evaluation<sup>9</sup>

T&E should be conducted to verify that systems, equipment, and facilities:

- Can be operated, maintained, and supported within the intended users' performance capabilities without exceeding cognitive and physical limitations as specified by competency and proficiency standards; and
- Meet design criteria.

### C.2.4 HSI Domains

Although each domain is considered and addressed individually, invariably, some system design decisions will affect multiple HSI domains. Optimizing total system performance entails holistic mission and desired operational capability assessment for trade-offs across the HSI domains to determine the most **effective**, **efficient**, and **affordable** solution, based upon system priorities and within acceptable levels of risk. Therefore, it is important to look at these domains together, remaining aware of their interdependence throughout the system's life cycle. By basing design decisions on thorough consideration of the *interdependent considerations across all HSI domains* during all stages of a system acquisition effort, you will achieve the goals of HSI.

#### C.2.4.1 Manpower

The consideration of the net effect of systems on overall human resource requirements and authorizations (spaces). This is to ensure that each system is affordable from the standpoint of manpower. It includes analysis of the number of people (military, civilian and contractor) needed to operate, maintain, repair and support each system being acquired.

#### C.2.4.2 Personnel

The consideration of human aptitudes, knowledge, skills, abilities, and experience levels that are needed to properly perform job tasks across the: military, civilian, contractor work force to operate, maintain, and support a system in peacetime and war. Personnel factors are used to develop the DoD Component personnel system classifications and civilian job series of system operators, maintainers, trainers, and support personnel. These are the "faces" that fill the authorized "spaces".

#### C.2.4.3 Training

Training is the learning process by which personnel individually or collectively acquire or enhance predetermined job-relevant competencies and proficiencies. This is done by developing their cognitive, physical, sensory, and team-dynamic abilities. Within HSI, training is the use of analyses, methods and tools to ensure systems training requirements are fully addressed and documented by systems designers and developers. This is done to achieve a level of individual and team proficiency that is required to successfully accomplish tasks and missions. Training systems must be standardized and ensure that the training objectives are met through the delivery of instructional methods, media and personnel, and system support through the life cycle.

---

<sup>9</sup> Source: MIL-HDBK-46855A 4.1.1.3.

#### **C.2.4.4 Human Factors Engineering**

The technical consideration and application of the integration of design criteria, psychological principles, human behavior, capabilities and limitations as they relate to the design, development, test, and evaluation of systems. The goal is to optimize performance of trained users/operators, through efforts focused on elimination of design induced errors. Secondly, it ensures that system operation, maintenance, and support are compatible with the total capabilities and limitations of users operating or maintaining those systems.<sup>10</sup>

#### **C.2.4.5 Survivability**

The consideration of the characteristics of a system that reduce susceptibility of the total system to mission degradation or termination. The goal is to reduce detectability of the warfighter, prevent attack if detected, prevent damage if attacked, minimize medical injury if wounded or otherwise injured, and reduce physical and mental fatigue. These issues must be considered in the context of the full spectrum of anticipated operations and operational environments and for all personnel who will interact with the system. Adequate protection and escape systems must provide for personnel and total system survivability when they are threatened with harm.

#### **C.2.4.6 Environment**

The consideration of Environment is important in that it affects concepts of operation and the capability requirements to protect the human user as well as the systems from the operational environment and the environment from the human users and systems' operations, sustainment and disposal.

#### **C.2.4.7 Safety**

The development of system design characteristics and procedures to minimize the risk of accidents and mishaps that cause death or injury to operators, maintainers, or support personnel. This also includes characteristics that threaten the operation of the system or cause cascading failures in other systems. Safety analyses and lessons learned are used to aid in development of design features that prevent safety hazards to the greatest extent possible and manage safety hazards that cannot be avoided.<sup>11</sup>

#### **C.2.4.8 Occupational Health**

Focuses on system design features and procedures that serve to minimize the risk of injury, acute or chronic illness, disability, and enhance job performance of personnel who operate, maintain, or support the system. Occupational health analyses and lessons learned are used to aid in development of design features that prevent health hazards where possible. They also provide recommendations on personal protective equipment, protective enclosures, or mitigation measures where health hazards cannot be avoided.

#### **C.2.4.9 Habitability**

Consideration of the characteristics of systems focused on satisfying personnel needs which are dependent upon physical environment. Habitability analyzes factors of working conditions and accommodations that are necessary to sustain the morale, safety, health, and comfort of the user population that contribute directly to personnel effectiveness and mission accomplishment.<sup>12</sup>

---

<sup>10</sup> MIL-STD 1472F.

<sup>11</sup> Sources: MIL-STD 1472F 4.5/8, MIL-STD 882D/E.

<sup>12</sup> Source: MIL-STD 1472F 4.4 a/e/f/i.

### C.2.4.10 Manpower

#### C.2.4.10.1 *Prominent Issues and Topics Encountered in the Manpower Domain*

The Manpower domain is chiefly concerned with the *number* of people needed. MIL-HBK 46855A presents the following issues and topics that fall under the purview of the Manpower domain:

- Wartime/peacetime manpower requirements;
- Deployment considerations;
- Force and organizational structure;
- Operating strength;
- Manning concepts;
- Manpower policies;
- Future technology and human aptitudes;
- System MERs;
- Basing options and implications for opening or closing bases; and
- Life cycle cost implications of manpower decisions.

#### C.2.4.10.2 *Manpower Domain and UAV Casualty Transport*

- If conceived and fielded correctly, the use of this technology for casualty transport should not require any additional manpower to operate or perform this function; however success in its use would conceivably lead to an ever growing demand for this capability in the field, leading to an overall increased demand for both aircraft and the Manpower to operate and maintain them.
- Use of this technology should benefit overall manpower issues by increasing survival of personnel wounded on the battlefield.
- Increased technological complexity of UAVs due to additional demands to provide medical support to wounded patients while in transit may increase manpower requirements associated with supporting these aircraft.
- A sufficient number of people with the required medical skills to fully utilize this capability in the field may not be available. Manpower shortages can often lead to commanders facing the issue of being forced to “use what they have”, even when the personnel do not possess the required skill-sets. This can also apply to UAV operator and maintainer personnel.

### C.2.4.11 Personnel

#### C.2.4.11.1 *Prominent Issues and Topics Encountered in the Personnel Domain*

The Personnel domain is chiefly concerned with the *type* of people (aptitude, experience, knowledge, skills, and abilities/attitudes) needed. MIL-HBK 46855A presents the following issues and topics that fall under the purview of the Personnel domain:

- Personnel selection and classification;
- Demographics;
- Accession and attrition rates;

- Career progression and retention rates;
- Promotion flow;
- Personnel and training pipeline flow;
- Qualified personnel where and when needed;
- Projected user population/recruiting;
- Cognitive, physical, educational profiles; and
- Life Cycle Cost implications of personnel decisions.

*C.2.4.11.2 Personnel Domain and UAV Casualty Transport*

- Any increase in personnel requirements in the field (i.e. for combat medics) necessary to enable the proper use of the UAV casualty evacuation capability will also increase the field medic (and perhaps combat soldier basic medical) training requirement to accomplish that. This would also apply to maintainers who would have to provide the additional support capability of medical equipment in the UAV, if any is so located.
- Any unique aircraft performance challenges associated with UAV CASEVAC might drive additional UAV operator selection and training requirements in order to keep the aircraft flying within acceptable “human / casualty tolerances / limitations”.
- A decrease in personnel requirements may lead to a decrease in safety. For example, the system design may need to change to accommodate the safety of potentially less qualified personnel. This speaks NOT ONLY to operators and maintainers, but should also take into account the “users” at the front line – the combat medic or basic soldier. If the UAV is inherently dangerous to be around, it could inflict injuries on the very personnel trying to utilize it to save another life. And the very chaotic circumstances that may attend the use of the device (a very “hot” LZ) can lead to even greater chances of injuries from such a device, much as is the case for helicopters.
- Less capable (lower selection standards or trained to a lower standard) UAV operators and maintainers will certainly run a greater risk of error leading to a greater risk of loss of the UAV. And anything that negatively impacts the “survival” of the UAV itself, therefore also directly negatively impacts the survival of the casualty inside it.
- Less capable combat medics or basic soldiers may not know how to best utilize the UAV for their wounded comrade resulting in decreased medical care for him while in flight, or they may even inadvertently commit errors in “packaging” him in the UAV, resulting in worsening of his wounds or actual additional injury as a result of his subsequent flight.
- Human Factors Engineering (HFE) must use analysis, design, testing and evaluating to ensure the system is built to accommodate the characteristics of the user population. This “user population” is NOT only the operators and maintainers, but rather also the front line medics and even basic soldiers trying to utilize the device at the point of injury, perhaps even in the midst of battle. Certainly the casualty will represent a “population” whose “characteristics” must be “accommodated” if they are to survive the flight.

**HOWEVER:**

- If conceived and fielded correctly, the use of this UAV technology for casualty transport should not require any increased personnel requirements to operate or perform this function; it should be



designed in such a way that very little (ideally no) additional training is required to properly prepare and load a casualty onto the aircraft for transport.

- Any soldier in the field should be able to utilize the aircraft for casualty transportation.
- No specialised medical qualifications should be required in order to utilize this technology.
- UAV design complexities or deficiencies in the configuration and use of the aircraft for casualty transport might inadvertently lead to a need for unique non-medical skills that are not present in the field medics seeking to utilize the aircraft. Conversely, this could also include the design of UAV medical equipment and gear which or may not be too complex for available military personnel in the field. A complex system that is difficult to operate may require personnel with expert knowledge or experience to operate the system to its full potential. When the system is operated by personnel without the proper knowledge, skills and training, the system may become inefficient, non-functional, or may be prone to errors. Without proper training or experience, UAV operators, maintainers or field medics may be unable to determine the potential risks associated with certain actions. Failure to account for potential dangers may result in poor decision-making, which may in turn prompt an action with an unnecessarily high risk for the casualty.

### C.2.4.12 Training

#### C.2.4.12.1 *Prominent Issues and Topics Encountered in the Training Domain*

The Training domain is chiefly concerned with *acquiring and maintaining job-relevant proficiency*. MIL-HBK 46855A presents the following issues and topics which fall under the purview of the Training domain:

- Training concepts and strategy;
- Training tasks and training development methods;
- Media, equipment, and facilities;
- Simulation;
- Operational tempo;
- Training system suitability, effectiveness, efficiency, and costs;
- Concurrency of system with trainers;
- Embedded, emulation, virtual applications;
- Training vs. job aids; and
- Timeliness of delivery.

#### C.2.4.12.2 *Training Domain and UAV Casualty Transport*

- Increased technological complexity of UAVs due to additional demands to provide medical support to wounded casualties while in transit may increase training requirements associated with supporting these aircraft. With every increase in technological capability for casualty care onboard the UAV will come an increase in training requirement for the “loader” to be able to properly configure both the aircraft and the patient prior to take-off; as this may not be a frequent task, retention of the training becomes problematic. UAV design complexities or deficiencies in the configuration and use of the

aircraft for casually transport might inadvertently lead to a need for unique non-medical skills that are not present in the field medics seeking to utilize the aircraft. Conversely, this could also include the design of UAV medical equipment and gear which may be too complex for available military personnel in the field. A complex system that is difficult to operate may require personnel with expert knowledge or experience to operate the system to its full potential. When the system is operated by personnel without the proper training, the system may become inefficient, non-functional, or may be prone to errors. Inadequately trained combat medics or soldiers may not know how to best utilize the UAV for their wounded comrade resulting in decreased medical care for him while in flight. Such inadequate training could lead to inadvertent errors in “packaging” the casualty in the UAV. This could lead to worsening of his wounds or actual additional injury as a result of his subsequent flight. Without proper training or experience, UAV operators, maintainers or field medics may be unable to determine the potential risks associated with certain actions. Failure to account for potential dangers may result in poor decision-making, which may in turn prompt an action with an unnecessarily high risk for the casualty. Therefore, no additional specialised training should be required in order to utilize this technology for casualty transportation.

- If conceived, designed and fielded correctly, the use of this technology for casualty transport should be such that very little additional training is required to prepare and load a patient onto the aircraft for transport; Any medic or soldier in the field should be able to utilize the aircraft for casualty transportation. Devices should not be so overly complex that training staff to use them becomes an extremely difficult task. Designs that are simple, intuitive, and based on commonly held schemas require very little training to achieve the desired level of proficiency. Device complexity may increase functionality, but it tends to do so at a cost of increased training requirements and a greater potential for error. An important trade-off exists between system complexity, design, and the training requirements to make it happen.
- Potential Solutions – UAV medical equipment should be designed to reduce training requirements associated with needless complexity. Developing an intuitive user interface can help medical personnel reduce the cognitive burden associated with operation of complex medical devices in the UAV. Equipment that is easy to use reduces or eliminates confusing or complex controls, labeling, or other factors affecting operation of the device. This reduces the amount of time necessary to train users, while reducing the potential for errors.
- Since the expectation is that UAVs would only be used for casualty evacuation on the battlefield, there would be no in-garrison opportunities for field medics or combat soldiers to use these devices for that mission outside of simulations. Training may not transfer from virtual or simulator technologies to real-world situations. Training and wartime environments differ in terms of specific user/task/environment relationships, stress, motivation, and consequences. These differences may lead to problems with transfer of training.
- Consideration must be given to the cost of providing high fidelity simulator training and other virtual training environments that often have costly startup budgets. Immersing students in this environment prior to deployment will create more realistic expectations among the field medics and basic soldiers and reduce the risk of certain false expectations that lead to low morale and disillusionment with the real capabilities of the technology.
- Training must adequately address risks present in the environment to ensure safety. Personnel will need training on hand washing, potable water, vector control, waste disposal, environmental contamination, radiation, and how to behave and how to treat casualties transported from an NBC threat situation. Also training on the proper use of any required personal protective gear, especially that associated with maintenance OR the proper avoidance of or subsequent cleanup of residual

biohazards in the UAV cargo area from transported casualties (i.e. blood, human waste, even residual CBRN materials brought in on the casualty).

- Medical personnel in the field must be trained to properly estimate risks / conduct triage associated with the appropriate use of the UAV for casualty transport, to reduce the risk they will engage in risky behaviors with potentially harmful outcomes for those transported.
- Non-medical personnel (i.e. combat soldiers) certainly are at risk of such risky behaviors if/when attempting to utilize UAVs for casualty transport.

### C.2.4.13 Human Factors Engineering

#### C.2.4.13.1 *Prominent Issues and Topics Encountered in the Human Factors Engineering Domain*

The Human Factors Engineering domain is chiefly concerned with *integrating design criteria with human behavior, capabilities, and limitations*. MIL-HBK 46855A presents the following issues and topics that fall under the purview of the Human Factors Engineering domain:

- Unnecessarily stringent selection criteria for physical and mental capabilities;
- Compatibility of design with anthropometric and biomedical criteria;
- Workload situational awareness, and human performance reliability;
- Human – system interface;
- Implications of mission and system performance requirements on the human operator, maintainer, supporter;
- Effects of design on skill, knowledge, and aptitudes requirements;
- Design-driven human performance, reliability, effectiveness, efficiency, and safety performance requirements;
- Simplicity of operation, maintenance, and support; and
- Costs of design-driven human error, inefficiency, or ineffectiveness.

#### C.2.4.13.2 *HFE Domain and UAV Casualty Transport*

- Increased technological complexity of UAVs due to additional demands to provide medical support to casualties while in transit may increase manpower, training, maintenance and logistic requirements associated with supporting these aircraft. HFE is the primary arena in which aspects of the UAV design which impact accommodating the human casualty carried in it are considered – aircraft originally designed to carry inert cargo may have very limited (or utterly insufficient) capability to safely accommodate any human, much less a seriously wounded one, in flight. HFE must inform all aspects of UAV performance and storage design as well as operational deployment to minimize risk to the casualty. HFE principles and standards not only must shape the design of future UAVs, but also must be applied to current aircraft to assess their suitability for casualty evacuation, and/or inform what modifications are necessary for current aircraft in order to make them suitable for this mission; The HFE capabilities of any given UAV should direct doctrine in how to deploy and utilize such aircraft – for example, primitive medical/human accommodations on board will limit the duration of flight one can expect for a casualty without leading to an increased risk of complications in flight.

- Designs that fail to consider the broad needs of the intended user population (i.e. medics or combat soldiers) may unnecessarily complicate use for certain operators. For example, devices that employ technical language may confuse the lay user (medic, soldier), whereas devices that rely heavily on textual displays or labels may introduce an unnecessary language barrier. UAV medical equipment and gear that fails to accommodate the needs of certain classes of field medical “operators” can have several negative outcomes. Reduced usability can result in user inefficiency or increase the potential for errors. Both may present significant health or safety risks to field medical personnel or the casualties. Forced to address usability issues themselves, the “user population” (field medics, soldiers) may resort to improvising procedures, employing ad hoc modifications, or burdening the training load with workarounds. A poorly designed user interface that lacks appropriate, salient feedback can lead to undetected medical errors that threaten the life of the patient.
- The austere environment encountered during UAV evacuation of casualties presents factors that can affect the operation of medical equipment and gear onboard. Those factors include:
  - Changes in altitude;
  - Vibration;
  - Three dimensional Inertial/Acceleration Forces;
  - Lack of Space; and
  - Limited Sources of Power.
- As the aeromedical evacuation aircraft gains altitude, partial pressure decreases even in pressurized cabins. As a result, oxygen monitors under-read the oxygen percentage at higher altitudes. Ventilators must monitor ambient pressure and compensate for deviations; otherwise, remote operators must be able to tele-connect to “manually” adjust ventilators. The situation is more complicated when in a combat zone requiring more aggressive “tactical” take-off and landing maneuvers by the vehicle. A mechanical ventilator suitable for UAV transport should adjust its parameters and modality of mechanical ventilation based on an analysis of atmospheric changes and its effects on patients. Decreased pressure also affects medical equipment and gear that contains air. Bubbles may be formed or expand in fluids. Rapid changes in altitude are typical during tactical take-off and landing resulting in rapid changes in pressure, temperature, and relative humidity.
- Medical equipment and gear used on UAVs must be able to withstand three dimensional inertial/acceleration forces. Monitoring devices may become unreliable in such conditions because variables such as ECG and pulse oximetry may generate multiple artifacts. Additionally, medical equipment must be able to resist damage caused by inertial/acceleration forces experienced during flight.
- The casualty themselves must also be able to “resist damage” caused by inertial forces experienced during flight – many injuries can be exacerbated by violent external forces applied against them, leading to worsening of any injury or even in extreme exposures, cause *new* injuries.
- Vibration can also cause damage to the interior parts of medical equipment or cause monitoring probes to move, resulting in faulty readings.
- Any increase in HFE could increase the systems *vulnerability* to electromagnetic forces. It is well known that on-board electrical systems can produce Electromagnetic Interference (EMI). EMI has the potential to create Electromagnetic Compatibility (EMC) problems with other medical equipment. EMI can lead to abnormal functioning or suspended functioning of devices in the proximity.
- Self-protection systems or electronic weapons may interfere with medical equipment and gear operation onboard the UAV. Unprotected electronic medical equipment could be damaged by

exposure to an Electromagnetic Pulse (EMP) in-flight. Weapons developed to disrupt electronic equipment (e.g. electromagnetic pulse or EMP weapons) are typically considered non-lethal in normal circumstances, but would be life-threatening in a UAV CASEVAC settings. For example, the function of on-board life-supporting medical equipment may be affected by this type of weapon and could potentially lead to the harm to or death of the casualty.

- Ideally, Medical equipment should be protected by the addition of electronic protection circuitry or electromagnetic shielded chassis enclosures or other means to control EMP and EMI potential issues. However, it is not known what the cost and difficulty of developing an EMP protection for all the medical equipment in use there would be. This clearly would have a negative effect on the survivability of any medical equipment in the UAV and therefore also the casualty being transported.
- Rapid removal of the casualty from the battlefield by UAV could possibly result in the loss of transmission of critical patient condition/care information from the point of departure to the arrival at the next level of Medical Care; there is a crucial need for the preservation and transmission of casualty health status/record of medical care from the point of departure to the providers at the other end of the UAV transportation chain.

### C.2.4.14 Survivability

#### C.2.4.14.1 *Prominent Issues and Topics Encountered in the Survivability Domain*

The Survivability domain is chiefly concerned with *evading, protection, and escaping from harm*. MIL-HBK 46855A presents the following issues and topics that fall under the purview of the Survivability domain:

- Threat environment;
- Fratricide Identification Friend/Foe (IFF);
- Potential damage to crew compartment and personnel;
- Camouflage/concealment;
- Protective equipment;
- Medical injury;
- Fatigue and stress;
- Impact of operational arenas (arctic, desert); and
- Impact of degraded operations (short/long term).

#### C.2.4.14.2 *Survivability Domain and UAV Casualty Transport*

- Current cargo UAVs are not designed with the principles of human survivability in mind; issues regarding detectability of the aircraft, or its ability to prevent, deter, defend or escape from attack are not primary design features for aircraft intended to carry inert cargo. Human protection and escape systems are not part of cargo UAV design or performance parameters. Therefore, in order to survive the UAV transport, the casualty must have a cargo space that is minimally “habitable” for such injured personnel – here, “habitable” equals “survivable” for the “casualty” occupant. The very nature of the “occupant” in the UAV (an injured and therefore to some varying degree disabled/incapacitated casualty) makes it very unlikely that they will be able to effectively escape unaided from a downed UAV or from anything leading to the downing of the UAV.

- Any changes to current UAVs to enhance survivability or install new capabilities will lead to increased weight and therefore decreased performance of the UAV, thus putting the craft at increased vulnerability to AA fires (i.e. a decrease in the “survivability” of the UAV and hence the casualty). This also will result in an increased complexity which thereby leads to increased opportunities for malfunctions in flight.
- Future design of such “survivable” UAV systems can lead to serious problems with trade-offs in performance.
- There will be certain phases of flight (take-off and landing, low-level / urban ops) in which the UAV is more vulnerable to enemy ground fire, leading to increased risk/decreased/survivability for the casualty inside.
- Survivability is a concern and a challenge in extreme environments such as space, undersea, desert, or arctic. This typically speaks only to the continued functionality of the UAV itself; however, the environment has a major impact on the “survival” of the *casualty* within the UAV (including the environment of flight) – every possible environmental parameter (air pressure, ambient O<sub>2</sub> and CO<sub>2</sub>, temp, light, vibration, G-forces, NBC contamination, etc.) will have some physiologic effect on the injured occupant; therefore measures taken to increase the survivability of the system *must* include mitigation of the environmental threats to the casualty; if the UAV “survives” *but* the *casualty* does *not*, then the mission was an abject failure.

#### **C.2.4.15 Environment**

##### *C.2.4.15.1 Prominent Issues and Topics Encountered in the Environment Domain*

The Environment domain is chiefly concerned with protecting the *system* (including here, the *patient*) from the *environment*, and the *environment* from the *system*. This section will have the largest discussion as it addresses the fundamental issues associated with this RTG. The following issues and topics fall under the purview of the Environment domain:

- Environmental conditions that impact the system (including the human);
- Biomechanical/biodynamic factors – impact, shock, and vibration;
- Extreme temperatures;
- Pressurization (e.g. underwater, high altitude, space);
- System hazards that impact the environment (water, air, land, space, and cyberspace);
- Noise pollution affects wildlife and local communities;
- Chemical emissions may affect quality of air, water, earth/soil, and other natural resources;
- And in this particular case, the biological contamination of the UAV due to human waste (blood, urine, feces) and/or battlefield WMD adherent to the casualty; and
- Disposal (garbage/waste products).

##### *C.2.4.15.2 Environment Domain and UAV Casualty Transport*

The ultimate goal involving this Domain is to *mitigate* the impact of the environment within and outside of the aircraft *upon the casualty*; certainly any ill effects upon the operators or maintainers should also be minimized



if only to help insure safety of flight issues for the human cargo. There is *also* a clear need to “mitigate” any impacts the environment might have upon the UAV carrying the casualty *as well as* any medical onboard medical equipment sustaining the life of that casualty en route. “Failure” of either one would lead to the death of the casualty and therefore the complete failure of that mission.

- Cargo UAVs are not designed with the principles of a human-compatible environment in mind; intended to carry inert cargo, the environment of the cargo hold was never designed nor intended for transporting a healthy human much less a *wounded* casualty; Protection from the UAV flight environment was not part of cargo UAV design or performance parameters.
- As noted above, Any changes to current UAVs to alter the cargo interior environment to be compatible with human life/health will lead to increased weight and therefore decreased performance of the UAV putting the craft at increased vulnerability to AA fires (i.e. a decrease in the “survivability” of the UAV and hence the casualty). This also will result in an increased complexity which thereby leads to increased opportunities for malfunctions in flight.
- The cargo space environment is a crucial factor with regard to impacting the health and safety of its human cargo – besides protecting the casualty from the aircraft cargo space environment itself (light, size/square feet, noise, temperature, etc.), the aircraft must also protect the casualty from the flight environment (altitude, ambient oxygen, temperature, vibration, G-forces, etc.).

One paper by Baker<sup>13</sup> describes the physiological and psychological effects of environmental stressors on patients. The author asserts that critically ill patients are even more susceptible to stress from environmental simulation due to their vulnerable state. Casualties can develop sensory overload from continuous lighting, crowding/cramped space, and noise. Along with any continuous monitoring onboard a UAV, engine and flight noises will be a constant source of stress. Individuals react differently to noise, but it is important to note that the threshold of tolerable sound is lower for ill people than for those in good health. Additionally, noise as a stressor may reduce an individual’s pain threshold. Noise can cause headaches, increase heart rate, increase blood pressure, and increase blood cortisol and cholesterol. Exposure to noise can also cause annoyance, irritability, anxiety, and sleep loss. Being in a small or confined space can intensify the problems associated with environmental stressors.

### C.2.4.15.3 Noise Protection

MIL-STD-1474D<sup>14</sup> is the noise standard imposed during the design and acquisition of U. S. military systems that provides specific noise limits and related requirements to equipment designers and manufacturers. The maximum limits in the standard are more stringent than the OSHA standards, and are applied to military materiel in place of OSHA standards. MIL-STD-1474D is intended to address noise levels emitted during the full range of typical military conditions, and provides criteria for designing systems having noise levels that:

- Permit acceptable speech communication in a noisy environment;
- Minimize noise-induced hearing loss;
- Minimize aural detection by an enemy;
- Minimize community annoyance; and
- Provide acceptable habitability of personnel quarters.

---

<sup>13</sup> Baker, C.F. (1984). Sensory overload and noise in the ICU: Sources of environmental stress.

<sup>14</sup> MIL-STD-1474D, Department of Defense Design Criteria Standard, Noise Limits, 2004.



The general requirements section of MIL-STD-1474D states that engineering controls are to be the primary means to protect personnel from noise hazards, and that personal hearing protection or safety procedures/measures (i.e. warning signs) will be used only after all noise reduction design approaches have been pursued.

MIL-STD-1474D describes steady-state noise categories and gives their associated limits for guidance in procurement activity decisions. The standard states, “If the total system configuration is unknown, the allowable noise limit for any single item shall be 3 dB below the limit of the applicable system category.” MIL-STD-1474D’s Table 1-I and Table 1-II, summarizing the requirement for determining conformance to steady-state noise limits in personnel-occupied areas. These requirements are applied to the acquisition and product improvement of all designed or purchased (non-developmental items) ground systems, sub-systems, equipment, and facilities that emit acoustic noise. The requirements are to be used for designing materiel to minimize hearing loss and to provide for acceptable speech communication in a noisy environment, and are intended for application during the full range of typical operational conditions. The applications of this differ depending on whether one is addressing the on board casualty being transported, the UAV operator or maintainer, or the field medic/combat soldier utilizing the technology. But certainly there are significant common areas associated with *short-term* exposures during casualty evacuation operations such as the ability to clearly communicate (including the field medic trying to communicate with the receiving medical unit, and medical personnel monitoring the casualty in flight being unable to communicate with the casualty and vice versa) and mitigating potential hearing injuries.

#### *C.2.4.15.4 Other Stressors*

Research has established that poor lighting, and/or excessively warm or cold temperatures can and will compromise human performance. Considering the total environment (i.e. the combined effects of heat, cold, vibration, noise, and light on the health, comfort, and performance of humans) includes the main effect of all those factors and their interactions<sup>15</sup>. All of these can adversely impact the ability of the “users” (i.e. field medic, combat soldier) to safely and effectively employ this transport capability for a wounded soldier. There can also be secondary consequences associated with these factors for the casualty himself.

- Excessive heat in situations where heavy work is performed has been studied extensively to help develop protective guidelines for the commercial work force and to understand how it affects military operations. Dissipating metabolic (body) heat is a complex process that depends on the work being performed, acclimatization, the air temperature, the radiant heat present, the humidity, air speed, and the clothing being worn<sup>16</sup>. This would be a major consideration especially for the casualty placed into the confines of the UAV compartment – already seriously stressed physiologically due to their injuries, any added environmental stressor such as excessive heat within the compartment will only worsen the injured state of the casualty.
- Cold weather has the effect of reducing tactile sensitivity and impairing performance on tasks requiring fine manual dexterity. Hand-grip strength decreases 21 – 28% after three hours at -25 degrees.
- Modern armies typically have thermally protective garments and other means of keeping their soldiers out of extremely cold weather. However, bulky protective clothing (e.g. arctic gloves) often trades the performance deterioration due to cold to that due to the lack of manual dexterity from the heavy gloves<sup>17</sup>. UAV design *must* take this into consideration when considering medical monitoring and/or

<sup>15</sup> Parsons, K.C. (2000). Environmental ergonomics: A review of principles, methods and models.

<sup>16</sup> Miller, D. and Lawton, C. (2006). Human Performance Modelling for System of Systems Analytics: Combat Performance-Shaping Factors.

<sup>17</sup> Ibid.

care equipment placed in the UAV for en route monitoring and care – the medic/combat soldier must be able to access, utilize and properly configure any and all equipment for the casualty associated with the UAV device.

- Likewise, design considerations for the cargo compartment need to take into account a significant increase in size/bulk of any casualty associated with severe cold weather field clothing. If there is no cargo compartment environmental control capability such that the temperature in the compartment can be significantly adjusted to protect the casualty from ambient temperatures, then they will have to be transported while still wearing their own cold weather field gear to avoid/prevent the onset/addition of hypothermia to their already dangerously compromised physical condition.
- Vibration can negatively impact cognitive functions and can induce decrements in time-sharing, memorization, inductive reasoning, attention, and spatial orientation. Whole-body vibration can have serious performance effects on soldiers. For example, the tolerance limit for accelerations of  $3 \text{ m/s}^2$  at 5 Hz is one minute, while at  $0.3 \text{ m/s}^2$  at the same frequency is eight hours. At very low frequencies, less than 0.5 Hz, motion sickness occurs. At 30 Hz, the resonant frequency of the eyes, vision is disrupted<sup>18</sup>. Given that these all involved *healthy* personnel, the impact of any deviations from these standards upon a *seriously injured* person would only be expected to worsen the casualties condition.
- Lighting within the UAV can have an impact on all the personnel working with the device. Obviously there is a need for maintainers to see what they are working on; but the medics and combat soldiers wanting to load a casualty into the UAV will need adequate lighting in order to assure proper casualty loading has been done. However, this can also expose the entire group, medics and casualties, to hostile fires if the lighting is too bright – this raises the possibility of NVG compatible lighting inside the cargo areas.
- Also, the casualty will not want to be forced to travel inside a closed tight container without some form of light inside the compartment, if only to avert additional psychological distress. Also, any medical personnel wanting to tele-monitor the patient en route will need adequate lighting inside the cargo area to properly and adequately visualize the casualty.

#### C.2.4.15.5 *Impact of Environment Upon UAV/Medical Devices*

The austere environment encountered during UAV evacuation of casualties presents factors which also can affect the operation of *medical equipment onboard*. Those factors include:

- Changes in altitude;
- Vibration;
- Three dimensional inertial forces;
- Lack of space;
- Limited sources of power; and
- Electromagnetic radiation.

#### C.2.4.15.6 *Altitude*

As the aeromedical evacuation aircraft gains altitude, partial pressure decreases even in pressurized cabins. As a result, oxygen monitors under-read the oxygen percentage at higher altitudes. Ventilators must monitor

---

<sup>18</sup> Ibid.

ambient pressure and compensate for deviations; otherwise, remote operators must be able to tele-connect to “manually” adjust ventilators. The situation is made even more complicated in a combat zone requiring tactical take-off and landing. A mechanical ventilator suitable for UAV transport should adjust its parameters and modality of mechanical ventilation based on an analysis of atmospheric changes and its effects on patients. Decreased pressure also affects medical equipment and gear that contains air. Bubbles may be formed or expand in fluids. Rapid changes in altitude are typical during tactical take-off and landing resulting in rapid changes in pressure, temperature, and relative humidity.

#### *C.2.4.15.7 Inertial Forces*

Medical equipment and gear used on UAVs must be able to withstand three dimensional inertial forces. Monitoring devices may become unreliable in such conditions because variables such as ECG and pulse oximetry may generate multiple artifacts. Additionally, medical equipment must be able to resist damage caused by inertial forces experienced during flight. Vibration can also cause damage to the interior parts of medical equipment or cause monitoring probes to move resulting in faulty readings.

#### *C.2.4.15.8 Testing*

Prior to deployment, UAV medical equipment and gear should undergo thorough testing to determine if it is suitable for operation in the austere environment (for an example, see Dahlgren, et al.<sup>19</sup>). McGuire<sup>20</sup> provides a list of test variables that should be considered:

- Electromagnetic compatibility (see below);
- Conducted emissions;
- Radiated susceptibility;
- Conducted susceptibility (low frequency);
- Conducted susceptibility (high frequency);
- Electrostatic discharge;
- Shock, drop, and topple survivability;
- Altitude;
- Sudden decompression (if in a pressurized UAV);
- Explosive decompression (if in a pressurized UAV);
- Vibration;
- Acceleration (crash conditions);
- Humidity;
- Mold growth;
- Salt corrosion;
- Fluid contamination;

---

<sup>19</sup> Dahlgren, B.-E., Hogberg, R. and Nilsson, H.G. (1997). Portable, but suitable: Devices in prehospital care might be hazardous to patient or to aviation safety.

<sup>20</sup> McGuire, N.M. (2006). Monitoring in the field.

- Waterproofness;
- Temperature;
- Sand and dust-proofing; and
- Requirements of UAV aircraft design and technical authorities: aircraft electrical and mechanical interface requirements.

### C.2.4.15.9 *Electromagnetic Environment*

- A different aspect of the “environment” would be the *electromagnetic* environment of the UAV. Self protection systems or electronic weapons may interfere with medical equipment and gear operation onboard the UAV. Unprotected electronic medical equipment could be damaged by exposure to an Electromagnetic Pulse (EMP) in-flight and it is well known that on-board electrical systems can produce Electromagnetic Interference (EMI). EMI has the potential to create Electromagnetic Compatibility (EMC) problems with other medical equipment. EMI can lead to abnormal functioning or suspended functioning of devices in the proximity. It is critical to take careful measures in designing and testing electrical equipment to minimize EMI. Medical equipment should be protected by the addition of electronic protection circuitry or electromagnetic shielded chassis enclosures or other means to control EMP and EMI potential issues.
- Weapons developed to disrupt electronic equipment (e.g. electromagnetic pulse or EMP weapons) are typically considered non-lethal in normal circumstances, but would be life-threatening in a UAV CASEVAC setting. For example, the function of on-board life-supporting medical equipment may be affected by this type of weapon and could potentially lead to the harm or death of the casualty. Using an EMP simulator, Vandre, et al.<sup>21</sup> demonstrated that 65% of unprotected electronic medical equipment could be damaged by the EMP from a nuclear weapon detonated 2,200 kilometers away. Ideally, medical equipment would be protected by the addition of electronic protection circuitry or electromagnetic shielded chassis enclosure of the UAV. However, it is not known what the cost and difficulty of developing an EMP protection for all the medical equipment in use.
- Using UAVs to transport battlefield casualties WILL expose the crews maintaining them to “occupational health threats” in the form of biological hazards inside the cargo compartment (blood, urine, feces, vomit as well as any CBRN material the casualties may have brought back on their bodies from the battlefield); not to mention explosion hazards if the casualties are not completely disarmed before placing them onboard.

### C.2.4.15.10 *Safety – Prominent Issues and Topics Encountered in the Safety Domain*

The Safety domain is chiefly concerned with *minimizing accidents and mishaps*. MIL-HBK 46855A presents the following issues and topics that fall under the purview of the Safety domain:

- Safety of design and procedures under deployed conditions;
- Human error;
- Total system reliability and fault reduction;
- Total system risk reduction;
- Additional topics and issues include:

---

<sup>21</sup> Vandre, R.H., Klebers, J., Tesche, F.M. and Blanchard, J.P. (1991). Minimising the effects of electromagnetic pulse (EMP) on field medical equipment (ECD No. 5043629). Washington, DC: Army Institute of Dental Research.

- Procedures – Normal and Emergency; and
- Systems safety areas of interest include (but are not limited to):
  - Human;
  - Weapon;
  - Ground equipment; and
  - NBC.

*C.2.4.15.11 Domain Interdependencies: Safety Trade-Offs and Considerations*

Improvements in safety may lead to:

- A decrease in manpower requirements if fewer people are needed for remediation actions; or
- An increase in manpower requirements if additional personnel (such as safety observers) are needed to improve safety.

*C.2.4.15.12 Safety Domain and UAV Casualty Transport*

Historically, safety related issues with regard to cargo UAV are connected to its “safe” operation, to the safety of its human *operators*, NOT with regards to carrying human cargo – aircraft originally designed to carry inert cargo may have very limited (or utterly insufficient) capability to safely accommodate any human, much less a seriously wounded one, in flight. Still any factors that make it safer to operate might also have a secondary benefit regarding the safety of human cargo.

- In the natural haste to load a casualty onboard a UAV (due to criticality of injuries and/or enemy threats), safety procedures may be ignored by field medics and combat soldiers, placing both the casualty and those loading them at increased risk of injury. Personnel may not fully understand the risks associated with failure to follow safety procedures if those risks are not effectively communicated during training. Additional training may be required both prior to and during deployment to ensure that personnel understand the risks associated with failure to follow safety procedures. However, training requires time and resources that may not be available.
- Since safety is mostly concerned with preventing accidents or mishaps, improvements to the system’s safety profile may likely also improve the ability of the system to escape harm (survive), since prevention is often the best medicine, and thereby benefit the casualty inside.
- However, it must be remembered that those same “safety” changes can ALSO add weight and cube to the UAV, thereby *decreasing* its *performance* capabilities and therefore also its *survivability* against AA and other ground fire threats in the operational environment. This obviously would have a deadly “side-effect” on the human cargo within it, should it be shot down.
- This also has to be weighed against the *increased* survivability that might occur for the casualty due to over-all safer operations of the UAV.
- Safety must inform all aspects of UAV performance and storage design as well as operational deployment to minimize risk to the casualty; Differences in the range of extreme environments will heavily influence system design characteristics and procedures to minimize the risk of accidents and mishaps. Obviously, the greater the range of environmental extremes, the greater the risk of accidents and mishaps for the UAV and its mission. This can be managed by increasing design factors / the robustness of the UAV to resist/counter the greater extremes; or one can limit the mission parameters to simply refuse to operate in those more extreme realms. This has been the method used for all

manned aircraft – the obvious advantage to using UAVs was that this allowed “operating” in extreme flight conditions that would be “unsafe” to human operators, but for whom the loss of an aircraft now would be only measured in some relatively fewer dollars and no human life lost, *hence worth the risk to fly. However*, now that casualty transport is considered, *all* of the same concerns regarding relative risk *to humans* in environmental extremes returns and is *worsened* since the UAV was never designed with “man-rating” in mind to start with.

- Rapid removal of the casualty from the battlefield by UAV could possibly result in the loss of transmission of critical patient condition/care information from the point of departure to the arrival of the next level of Medical Care; there is a crucial need for preservation and transmission of casualty health status/record of Medical Care from the point of departure to the providers at the other end of the UAV transportation chain.

### C.2.4.15.13 *OCCUPATIONAL HEALTH – Prominent Issues and Topics Encountered in the Occupational Health Domain*

The Occupational Health domain is chiefly concerned with minimizing incidents of injury, acute/chronic illness, disability and other *long-term health effects due to exposure to hazards*. MIL-HBK 46855A presents the following issues and topics that fall under the purview of the Occupational Health domain:

- Health hazards induced by systems, environment, or task requirements.
- Areas of special interest include (but are not limited to):
  - Acoustics;
  - Biological and chemical substances;
  - Radiation;
  - Oxygen shortage and air pressure;
  - Temperature extremes;
  - Shock and vibration; and
  - Laser protection.

### C.2.4.15.14 *Occupational Health Domain and UAV Casualty Transport*

All current occupational health related issues with regard to cargo UAV would be connected to its operational health impacts on the *operators and maintainers* and NOT with regards to any human cargo – aircraft originally designed to carry inert cargo may have very limited (or utterly insufficient) capability to accommodate any human in an occupationally healthy manner in flight, much less a seriously wounded one; still any factors that make it more “healthy” to operate and maintain might also have a secondary impact regarding the health of a human cargo; However, those issue have already been addressed in earlier domains and do not require repeating here. In the case of UAV casualty transportation, the “casualty” further introduces maintainers and others tasked with cleaning/regenerating the aircraft for another mission additional “environmental” hazards such as biological material (blood, human waste, and other bodily fluids) as well as any NBC contaminants that may have come along with the casualty directly from the battlefield. Due to space limitations in this RTG report, no additional space will be spent in discussing those occupational aspects associated with this technology regarding the operators or maintainers.



*C.2.4.15.15 Habitability – Prominent Issues and Topics Encountered in the Habitability Domain*

The Habitability domain is chiefly concerned with *working conditions* and *living accommodations* to the degree to which it impacts overall system performance. The Defense Acquisition Guidebook (DAG), Section 6.3.7.2 presents the following issues and topics that fall under the purview of the Habitability domain:

- Physical environment (e.g. adequate light, space, ventilation, sanitation, and temperature and noise control);
- Living condition (berthing, personal hygiene, privacy/personal space);
- Personal/support services (religious, medical, mess, social/interpersonal/recreational);
- Impact on meeting / sustaining mission effectiveness;
- Impact of quality of life of morale, recruitment, and retention; and
- Examples include requirements for heating and air-conditioning, noise filters, lavatories, showers, dry-cleaning and laundry.

*C.2.4.15.16 Habitability Domain and UAV Casualty Transport*

All habitability related issues with regard to cargo UAVs typically are connected to its operational health impacts on the *operators and maintainers* NOT with regards to any *human cargo* – aircraft originally designed to carry inert cargo may have very limited (or utterly insufficient) capability to accommodate a human in a healthy manner in flight, much less a seriously wounded one, still any factors that make it more “habitable” to operate and maintain might also have a secondary impact regarding the health of a human cargo due to more efficient effective and safer behaviors on the part of the operators and maintainers. These issues have already been addressed in the “Environment” domain. Due to space limitations in this RTG report, no additional space will be spent in discussing those habitability aspects associated with this technology regarding the operators or maintainers.



## **Annex D – THINKING OUTSIDE THE BOX: MEDICAL EQUIPMENT RECOMMENDATIONS FOR FUTURE CASEVAC/MEDEVAC UAVs**

### **D.1 USING UAVs TO PERFORM MEDICAL MISSIONS – MEDICAL CAPABILITIES (TREATMENT AND MONITORING)**

As has been discussed above in several places, the potential use of Unmanned Aerial Vehicles for casualty care falls into two broad categories: CASEVAC, in which casualty evacuation occurs without medical supervision or continued medical care, and MEDEVAC, in which there is continuity with medical care (if any) that has already been established, and which thus requires on-board medical capabilities and care personnel. Because CASEVAC UAVs will not have been specifically designed for casualty care, but will rather be used as vehicles of opportunity for evacuation, we cannot by definition require that medical equipment be kept onboard. However, given that UAVs will very likely be used for such purposes, we delineate below our suggestions regarding minimal capabilities that would facilitate casualty evacuation even without provider oversight so as to minimize the impact on the continuity of care. Thus, we have considered medical equipment which might be “nice to have” on a CASEVAC aircraft, just as it is “nice to have” on any other type of CASEVAC vehicle. Such equipment could conceivably be carried to the casualty, or placed on board at the location of the casualty, if available. The most important items are common medical care items such as litters and litter straps, IV fluids, and blankets, which may be available at the site of casualty pickup – therefore not needing to be permanently installed on the aircraft. For MEDEVAC, though implementation will likely not be realized in the near future, the situation is clearer, and we enumerate the equipment and conditions that we believe should be available before any such evacuation takes place. The ability to provide a certain level of care in flight is a *sine qua non* for MEDEVAC use of a vehicle, and in the future may actually be able to allow care in flight without the presence of a human attendant.

As technology keeps improving, better, smaller, and smarter monitoring capability is continually being offered. In order to avoid limiting the applicability of our recommendations and to allow for continued improvements and localisation of the medical systems on board, we offer only general outlines and minimum technical details.

#### **D.1.1 CASEVAC Missions**

This type of mission involves extracting casualties from the point of injury to Role 1 or 2 medical facilities (which will vary between different users, scenarios and conflicts), or potentially simply a short distance from the point of injury to a nearby location in which a field medic can provide stabilizing care while waiting for a true MEDEVAC aircraft. The casualty may be moved in order to provide him/her with advanced medical care, to allow the unit to continue its mission without having to care for the wounded warrior, or simply to remove someone from danger (e.g. a burning house). Flight time for these missions will be almost always necessarily short, on the order of a few minutes.

Strictly speaking, no medical capability is available *a priori*, and we thus can not offer guidelines *vis a vis* medical equipment for these vehicles of opportunity. In the interest of casualty safety, however, we specify conditions that should help commanders choose which UAVs should be preferentially repurposed (temporarily) for CASEVAC where better options do not exist or are not relevant. Ideally, even CASEVAC UAVs would include a minimum set of medical capabilities, which would better enable safe completion of the mission. Even in this ideal setting, however, by definition there is no medical provider on board and the

medical equipment is quite limited as CASEVAC is not the primary purpose for these vehicles. CASEVAC Basic desirable items could include:

- Interior Lighting, to enable safe loading and for patient comfort – ideally, we would like to see at least one low light source, close to the casualty's head (to be kept on during the entire journey) and two bright light sources (one at the head, the other at the lower part of the body) to allow post-boarding and pre-unloading care and possibly en-route self care.
- Communication with the evacuee and noise protection – systems that will allow audio and/or visual communication between the evacuee and a ground station (including equipping the UAV with a display monitor and supporting communication radios and systems) are highly desirable, if possible.
- Strapping/restraint mechanisms for the casualty – Restraint systems should allow safe transport of the casualty to avoid further injuries as the UAV maneuvers out of the combat zone. Spine immobilization apparatuses and padded floors are preferable (but not necessary, for the sake of rapid extraction and simplicity).
- The evacuee should be flown with the head towards the front of the UAV (to avoid a head down posture during take-off and landing; this is less relevant for rotary wing aircraft).
- The platform should be able to accept (from the viewpoint of space and weight considerations) loading casualties and support equipment (which may come from the casualty's unit, rather than the UAV's unit) to best enable continuity with any possible existing basic medical care, including:
  - Intravenous fluids – Hooks for hanging infusion bags should be available.
  - Oxygen supplementation – Highly desirable if available, even if it is provided by ground personnel when the Casualty is being loaded. There should be some mechanism for restraint of the Oxygen system, to preclude it causing additional injury to the casualty.
  - Hypothermia prevention (active and passive) – Spare electrical outlets for active hypothermia protection and/or other electrical equipment that may be loaded with the casualty are highly desirable, though we grant they may not be available in a cargo UAV used for opportune CASEVAC.

### **D.1.2 MEDEVAC Missions**

Designated medical transportation missions (MEDEVAC) require sophisticated equipment/medical personnel, and may last anywhere between tens of minutes and hours. These missions are currently accomplished by designated professional teams of experts, and they are unlikely to be replaced by unmanned systems in the near- to medium- term. The patient population generally includes severely wounded and sick patients, who have undergone operations or who require intensive care, and who will be accompanied by medical personnel capable of providing care in flight. Desired capabilities, in addition to all the requirements listed above under CASEVAC, could include:

- Communication system to allow communicating with conscious casualties, either by accompanying medical personnel or by ground personnel, if unaccompanied.
- Monitoring (in no particular order of preference):
  - Blood pressure monitors.
  - Invasive blood pressure monitoring (CVP, A-line).
  - EtCO<sub>2</sub>.
  - Thermometer (body temperature measurements).

- Urine output.
- Drain outputs (inc. chest drains and NG tubes).
- 12-lead ECG capability.
- Intracranial Pressure (ICP) monitoring.
- Heart rate variability/complexity monitor (these might be replaced by any other technology that would mature and will prove relevant in the coming years, which is applicable to everything else on the list that might be taken off or replaced in the future).
- Accelerometers.
- Treatment capabilities (with autonomous and remote controlled functions):
  - Oxygen supplementation (at least 6 liters per minute per casualty, could be 3 liters per minute if closed loop systems and smart ventilators that allow for  $\text{FiO}_2 > 0.8$ ) are used.
  - Mechanical ventilation (automated, closed loop system, that will control the ventilation, including  $\text{FiO}_2$ , rate, tidal volume, pressure, PEEP, etc.), according to the patient's needs, oxygen saturation and hemodynamic status. Remotely controlled ventilator settings should be possible.
  - Infusion pumps (IV fluids, medications, anesthesia).
  - Suction.
  - Analgesia (Patient Controlled).
  - Intermittent sequential pneumatic compression devices (DVT prophylaxis).
- Other desirable capabilities or attributes:
  - Pressurized cargo/patient cabin to maintain an acceptable cabin altitude.
  - Food and drinking fluids (for conscious patients).
  - Cabin climate control (Prolonged hypothermia prevention measures and cooling systems).
  - Possible 30 degrees head rise (for traumatic brain injured casualties).
  - Padded floor/mattresses for improved comfort.
  - Strapping and space to allow fitting a patient on a back board and/or litter.
  - Spare medical materiel to refresh the ground forces' supplies.

### **D.1.3 MEDEVAC Desirable Equipment Technical Details**

- All medical equipment should be airworthy, and certified for this use by the appropriate national body.
- While not in use, the equipment should be locked inside the patient chamber. Space for all the wiring should be included.
- There should be redundant pulse oximetry, 3-lead ECG, and ventilation capabilities, to allow functioning for at least half of the duration of the longest flight planned for this UAV. The backup systems should be connected to the UAV's communication systems.
- "All in one" systems (requiring less space) and "closed loop" (include feedback mechanisms that allow autonomous control of the system's output) are preferable.

- A single screen will display all the relevant patient data gathered, and may optionally also turn to face the casualty to provide entertainment.
- All the medical data recorded (including monitor and treatment) should be stored on board and included in the “black box”.
- The urine and drains output should be placed lower than the casualty’s trunk, to allow drainage and a scale, for output measurement.
- Analgesia administration options should include both PCA (Patient Controlled Analgesia) and automatic infusion pumps (both remote and local-automated controlled). Automated control requires both computerized control system that follows pre-determined algorithms and some sort of EEG\anesthesia depth sensors, as feedback. Such a device can control the administration of the sedation drugs to the anesthetized patient and maintain adequate level of analgesia\anesthesia during the flight.
- The oxygen and suction sockets should be located near the head of the evacuee.
- The probe for the ICP monitor should be placed near the head of the evacuee, as should be the probe for the EtCO<sub>2</sub>. The Blood pressure probe and the invasive blood pressure probes should be placed near the upper half of the evacuee’s body.
- Minimum wiring should be preferred. Maximum use of wireless sensors (taking into account the requirement to not interfere with the UAV’s operation) or joining a few sensors’ wiring is preferred.
- At least three free (additional) standard power sockets should be available for adding other medical equipment for the duration of a flight (at the head, the trunk and the lower part of the body of the evacuee). The output should use standard voltages (generally 24 V).
- Three points (again, at the head, mid-body, and lower extremities) should be available for affixing equipment to secure it during flight.
- Pre-packed re-supply medical equipment should include the standard and most commonly used equipment (for example IV bags, tourniquets, syringes, etc.).

## **D.2 CONCLUSION**

UAVs used as vehicles of opportunity for CASEVAC should meet basic criteria to help ensure casualty safety and minimize en-route deterioration. It is unlikely that the vehicle will come pre-equipped with such equipment, but it is desirable that attachment/fixation points be installed in all cargo UAVs which may be used for this purpose. These vehicles will not be appropriate for all evacuations for clinical, safety, and ethical reasons, as discussed above. MEDEVAC UAVs necessarily would offer better solutions to casualty transport challenges, if such aircraft are designed and made available, and should ideally have available the minimum criteria enumerated above. In light of continuing developments in medical technology, we recommend that this document (and these criteria, specifically) be viewed as “living”, thus requiring periodic reassessment. Development and fielding efforts to produce true “closed loop”, fully autonomous or remotely adjustable capabilities which may be suitable for use in the UAV environment, must be pursued. Such capabilities may significantly enhance the potential use of UAVs in the MEDEVAC role.

## **Annex E – POTENTIAL FUTURE USE OF UAVs FOR TACTICAL AND STRATEGIC MEDICAL EVACUATION**

Chapter 9 considers casualty and patient movement within the area of operations (CASEVAC and Forward MEDEVAC). This annex examines recent advances in tactical and strategic aeromedical evacuation. Whilst not directly related to the topic of UAV CASEVAC, consideration of the nature of tactical and strategic aeromedical evacuation is important within the context of evolving UAV technology and capabilities.

### **E.1 TACTICAL AEROMEDICAL EVACUATION**

Within an operational theatre, tactical aeromedical evacuation assets perform the movement of patients between medical facilities. These assets provide movement of patients to a higher level of care or to a temporary holding area, prior to onward strategic aeromedical evacuation. Maguire<sup>1</sup> states that effective care requires a thorough knowledge of device capabilities and limitations and medical personnel require proper training to survive and function in the environment to be able to care for and protect their patients. Maintaining the level of clinical care, which was being delivered at the originating facility, while in-flight, is an important principle of the tactical and strategic aeromedical evacuation systems; if care were not to be maintained or enhanced, morbidity and mortality would increase, and the ethical issues involved in the use of this modality would increase (see Chapter 8). Venticinque et al.<sup>2</sup> recognised this and the importance of paying close attention to logistical detail, preparing for a wide diversity of patients and illnesses and leveraging all available resources, including aeromedical evacuation to ensure the quality of care in the field. In tactical AE, transit time is relatively short when compared to strategic flights; notwithstanding this, a high level of clinical care may be required to maintain a patient without detrimental consequences, particularly given that the movement is so soon after wounding or illness; this requires considerable planning and logistic provision.

Tactical and strategic aeromedical assets comprise airframes, personnel and equipment. While the vast majority of patients may be safely and appropriately moved with basic nursing care, some patients require highly specialised equipment and teams. Many of the clinical capability advancements of the strategic aeromedical evacuation system are also required to be provided within the tactical system. Within NATO, many Nations possess the ability to move ventilated critical care patients; teams comprising appropriately trained medical personnel and equipment are able to perform this task.

#### **E.1.1 Peripheral Nerve Block Catheters**

A recent advance in analgesia has been the use of peripheral nerve block using catheters. Instead of attempting to control pain with strong opioid medication with the resultant systemic effects, some patients can be successfully treated with a peripheral nerve block catheter. These catheters can be inserted at selected Field Medical Treatment Facilities; when correctly sited and working, they can provide exceptional analgesia, without the usual concern about the respiratory depression complications of opioid analgesia. These catheters and their elastomeric pumps are seen in the tactical and strategic aeromedical evacuation systems. While aeromedical teams require training in their use, the overall effect decreases patient dependence on in-flight medical care.

---

<sup>1</sup> Maguire, N.M. Monitoring in the field.

<sup>2</sup> Venticinque, S.G. and Grathwohl, K.W. Critical care in the austere environment: Providing exceptional care in unusual places.

### **E.1.2 Staffing Differences**

International differences exist in the air evacuation team composition (medical capability), medical training, and equipment. In general, the national origin of the airframe and the medical team allowed to fly on-board are one and the same; for example, USA teams are allowed to fly on USA aircraft. Aircraft aeromedical equipment certification and aeromedical crew training in the context of the aircraft's operational crew and command are the determinants of this relationship. There are, however, some exceptions to this relationship, which have been agreed: The US and UK have reciprocal arrangements to fly each other's teams on nationally owned C-17 aircraft, under an arrangement called Interfly. Widening of the agreement to include the other Nations who own C-17 aircraft has been discussed and some provisions have been made. Extension of this agreement, for tactical use on C-130 aircraft, is currently in development. Within Europe, the European Air Group is debating potential Interfly arrangements. However, equipment certification is a major obstacle.

### **E.1.3 Potential Tactical UAV Use**

In the future, if UAVs were to be used in the tactical environment, provided their internal size and payload were suitable, the specifications for use for tactical aeromedical evacuation should be considered proactively and with greater unanimity. For some patients, however, their high clinical care requirements would necessitate a large team with a large quantity of equipment; therefore, for some patients, UAVs may not initially be suitable. These patients may require a vehicle, similar in capability to those able to conduct strategic AE. Safe vehicle selection for MEDEVAC will still require medical control.

## **E.2 MEDEVAC (STRATEGIC AEROMEDICAL EVACUATION)**

Strategic aeromedical evacuation typically involves the movement of larger numbers of patients per mission, compared with the preceding forms of aeromedical evacuation. By definition, their movement usually occurs over considerable distances, typically with far longer flight times than forward and tactical movements.

The various medical capabilities used in strategic AE are explored:

**Negative Pressure Wound Therapy (NPWT)** – NPWT can be a valuable adjunct in the management of severe soft tissue wounds; the US use the Wound VAC™ device on an estimated 20% of patients entering their strategic AE system from Afghanistan<sup>3</sup>. The devices can be used on a variety of wounds; they are not exclusively used on critical care patients; Fang et al.<sup>4</sup> showed that their use was feasible during strategic aeromedical evacuation missions.

**Critical Care** – The logistic requirements for the transport of critical care patients is considerable; heavy (up to 500 kg)<sup>5</sup> and large volumes of equipment<sup>6</sup> will preclude their movement on UAVs in the initial phase of their development. While the development of UAVs capable of delivering the strategic AE requirements may be considerably some way off, there are some recent advances in care within the strategic AE chain which should be considered; each are discussed below.

---

<sup>3</sup> Mollan, I.A. (Coalition Validating Flight Surgeon, Joint Patient Movement Requirements Center, US CENTCOM September – November 2010). US Bagram aeromedical evacuations with wound vac or patient controlled analgesia (PCA).

<sup>4</sup> Fang, E., Dorlac, W.C., Flaherty, S.F., Truman, C., Cain, S.M., Popey, T.L.C., Villard, D.R., Aydelotte, J.D., Dunne, J.R., Anderson, A.M. and Powell, E.T. Feasibility of Negative Pressure Wound Therapy During Intercontinental Aeromedical Evacuation of Combat Casualties.

<sup>5</sup> Turner, S. and Ruth, M. Critical Care Air Support Teams.

<sup>6</sup> Beninati, W., Meyer, M.T. and Carter, T.E. The critical care air transport program.



**Ventilation** – Barnes et al.<sup>7</sup> examined the ventilatory requirements, oxygenation and oxygen use in flight for US critical care patients; further studies into oxygen conservation systems including the closed loop control of FiO<sub>2</sub> were recommended. Further investigation of portable oxygen generation systems may provide adequate oxygen flow and reduce the need for compressed gas; thereby reducing the weight of required aeromedical equipment. Further development either reducing the logistic requirements or reducing the requirement for accompanying team members may in the future enable the consideration of movement of critical care patients using UAVs, though such use does not appear feasible in the near future.

**Enteral Feeding** – Victims of trauma require enhanced nutritional support; in ground, fixed care facilities, this nutritional support is administered by enteral feeding. The time during long-duration AE transfers could present an opportunity for exploitation; feeding could be provided. Enteral feeding, however, can result in complications, including micro-aspiration. Patient posture within aeromedical stretcher assemblies and the G forces associated with flight may however alter the complication characteristics. The USAF already performs enteral feeding on secondary strategic patient transfers, from Germany to the Continental USA (CONUS). Turner et al.<sup>8</sup> report that Royal Air Force (RAF) Critical Care in the Air Support Team (CCAST) are conducting a study to quantify the risk of micro-aspiration during primary strategic CCAST missions, from Afghanistan to the UK; the results will inform future UK enteral feeding policies, and potentially those of all Allied Nations carrying out strategic air evacuation.

**Burn Patients** – Renz et al.<sup>9</sup> found that during a four year period, over 500 patients with burns were evacuated from Iraq and Afghanistan to the US Army Institute of Surgical Research Burn Center in San Antonio, Texas, USA. Of these patients, with a mean burn size area of 16% total body surface area, about 40% were transported by the Burn Flight Team and about 32% transported by Critical Care Air Transport Team (CCATT). While some of these transports were able to be conducted without the need for additional team members, any increase in team size would add to the aerial platform's payload requirement.

**Haemofiltration** – The transfer of patients with acute renal failure to medical facilities for definitive treatment poses difficulty. Stevens et al.<sup>10</sup> reported upon two cases, one for short-duration, and the other for long-duration strategic AE missions, during which in-flight haemofiltration was administered. In extremis, this in-flight haemofiltration by a volumetric method, was recognised to represent a major advance for safe patient transfer. Currently, however, commercial haemofiltration devices operate utilising a system of weights and balances; these are unsuitable for use in the air, as they require a steady operating surface and would be affected by the turbulence and G in the air environment; their utilisation would be unfeasible in UAVs. Alternative methods to improve patient stabilisation, including the use of haemofiltration within field hospitals, are currently employed. The strategic transfer of patients with acute renal failure remains a challenging area; despite current treatments, close cooperation with strategic aircraft tasking authorities is essential to ensure that patient transfer occurs expeditiously and at a clinically appropriate time.

---

<sup>7</sup> Barnes, S.L., Branson, R., Gallo, L.A., Beck, G. and Johannigman, J.A. En-route Care in the Air: Snapshot of mechanical ventilation at 37,000 feet.

<sup>8</sup> Turner, S., Ruth, M.J. and Bruce, D.L. "In flight catering: Feeding critical care patients during aeromedical evacuation".

<sup>9</sup> Renz, E.M. "Aeromedical Evacuation of Burn Patients from Iraq".

<sup>10</sup> Stevens, P.E., Bloodworth, L.L. and Rainford, D.J. "High Altitude Haemofiltration".



**Acute Lung Rescue Team (ALRT)** – Dorlac et al.<sup>11</sup>, Fang et al.<sup>12</sup>, Allan et al.<sup>13</sup> describe the role of the US ALRT and Extracorporeal Membrane Oxygenation (ECMO) in the treatment and movement of patients with severe lung injury. In her paper, Walton describes the use of the ALRT and details the logistic requirements<sup>14</sup>; they are immense and far in excess of standard critical care. It is therefore likely that the movement of patients with severe lung injury will continue to be conducted by conventional means. As with patients requiring haemofiltration, close cooperation with strategic aircraft tasking authorities is essential to ensure that patient transfer occurs expeditiously and at a clinically appropriate time.

### **E.3 SUMMARY**

With enhanced available range, UAVs could conceivably provide long-distance transfer and strategic aeromedical evacuation on UAVs could become a possibility. Considerable available range and payload would be required if UAVs were to be able to conduct highly specialised medical missions, and such future use will be dependent upon significant improvements in medical technologies.

---

<sup>11</sup> Dorlac, G.C., Fang, R., Pruitt, V.M., Marco, P.A., Stewart, H.M., Barnes, S.L. and Dorlac, W.C. “Air Transport of Patients with Severe Lung Injury: Development and Utilisation of the Acute Lung Rescue Team”.

<sup>12</sup> Fang, R., Allan, P.F., Womble, S.G., Porter, M.T., Sierra-Nunez, J., Russ, R.S., Dorlac, G.R., Benson, C., Oh, J.S., Wanek, S.M., Osborn, E.C., Silvey, S.V. and Dorlac, W.C. “Closing the ‘Care in the Air’ Capability Gap for Severe Lung Injury: The Landstuhl Acute Lung Rescue Team and Extracorporeal Lung Support”.

<sup>13</sup> Allan, P.F., Osborn, E.C., Bloom, B.B., Wanek, S. and Cannon, J.W. “The Introduction of Extracorporeal Membrane Oxygenation to Aeromedical Evacuation”.

<sup>14</sup> Walton, C.S. “Aeromedical Evacuation (AE) From Afghanistan of a Patient with Serious Lung Injury Using the Acute Lung Rescue Team”.

## Annex F – KEY TERMINOLOGY/GLOSSARY

NOTE: Not all of these terms are currently formally defined within NATO – when possible, official definitions have been used throughout this text, but if not possible, then clarifying definitions have been used, even though they may not be official NATO terminology.

**AE:** Abbreviation for “Aeromedical Evacuation”. Occasionally incorrectly used to refer to both MEDEVAC and CASEVAC, though in standard usage it refers only to MEDEVAC.

**Airworthiness:** The ability of an aircraft or system to operate in flight and on ground without significant hazard to aircrew, ground crew, passengers (where relevant) or to other third parties (MC-0601).

**Airworthiness (2):** Also used to mean the ability of an aircraft or system (such as on-board medical equipment) to operate without hazard to the aircraft systems. Not a standard NATO usage.

**Automated System:** A system that, in response to inputs from its sensors, logically follows a predetermined set of rules to provide a predictable outcome, and which thus performs its task or function with little or no direct human control. For manned or unmanned platforms (air, land, maritime), various systems may be automated to relieve operator requirements, such as attitude controls (a.k.a. “autopilot”), environmental controls, target tracking, and take-off and landing. Non-NATO term.

**Autonomous:** The execution of predefined processes or events that do not require direct UAV System crew initiation and/or intervention. Non-NATO term.

**Autonomous System/Vehicle:** A system capable of sensing its environment, making decisions, and taking actions to bring about an optimal state, without direct human control. An autonomous system has the ability to understand higher level intent and direction, and to choose from multiple alternatives. Although its overall function is by design, individual actions and final outcome may be unknown. It may or may not have human oversight.

Rationale: Autonomous systems differ from automated systems in that they possess more advanced abilities to sense and respond to their environment, and the ability to make independent decisions and take appropriate actions.

**Casualty:** Any individual who is injured, ill, or wounded – prior to their entry into the medical care system. To be differentiated from Patient, q.v.

**Casualty Evacuation (CASEVAC):** The non-medicalised evacuation of patients without qualified medical escort.

Note: this term must be distinguished from Medical Evacuation. (AMEDP-13(A))

**Casualty Extraction:** Casualty movement from point-of-injury to a safer location where initial medical care can be provided by buddy aid, combat lifesaver aid, or combat medic care, prior to further medical evacuation.

**CCAST:** Critical Care in the Air Support Team (GBR term).

## ANNEX F – KEY TERMINOLOGY/GLOSSARY

---

**CCATT:** Critical Care Air Transport Team (USA term).

**CSAR:** Combat Search and Rescue – Pre-established procedures for the detection, identification, and recovery of Allied personnel in hostile territory. (AAP-6 – modified)

**ISAF:** International Security Assistance Force. NATO’s Operation in Afghanistan.

**ISTAR:** Intelligence, Surveillance, Target Acquisition, and Reconnaissance.

**Medical Evacuation (MEDEVAC):** The medically supervised process of moving any person who is wounded, injured or ill to and/or between medical treatment facilities as an integral part of the treatment continuum. (AMEDP-13(A))

**MERT:** Medical Emergency Response Team (GBR Term). MERT comprises a highly trained forward aeromedical team with specialised capabilities.

**Patient:** Any person who has entered the medical care system for diagnosis and/or treatment and who has not died nor been discharged. (AMEDP-13(A)). Must be differentiated from a casualty, who has not yet entered the medical care system, q.v.

**PEDRO (USA Term):** Call sign for the USAF Combat Search and Rescue aircraft, usually medically staffed by a paramedic.

**Remotely Piloted Aircraft (RPA) (USA Term):** A sub-set of RPV – in this case, “An unmanned aircraft which is piloted from a remote pilot station.” This term is increasingly used by the USAF instead of UAV. Not a NATO-approved term at this time.

**Remotely Piloted Vehicle (RPV):** A vehicle which is driven or piloted by a person who is not physically located in the vehicle – control inputs are by means of distance communication techniques.

**Rescue:** An operation to retrieve persons in distress, provide for their initial medical or other needs, and deliver them to a place of safety. (ATP-3.3.9.3 Draft)

**Search and Rescue:** The use of aircraft, surface craft, submarines, specialised rescue teams and equipment to search for and rescue personnel in distress on land or at sea.

**Unmanned Aircraft (UA):** An aircraft that does not carry a human operator and is operated remotely using varying levels of automated functions.

Notes:

- 1) Unmanned aircraft can be expendable or recoverable.
- 2) Unmanned aircraft may carry a lethal or non-lethal payload.
- 3) Cruise missiles are not considered unmanned aircraft.
- 4) ICAO considers “UA” to be an umbrella term, including free balloons, remotely piloted aircraft, and possibly others. To date, ICAO has not considered any “Autonomous Aircraft” as falling within this definition.

**Unmanned Aircraft System (UAS):** A system whose components include the unmanned aircraft, the supporting network and all equipment and personnel necessary to control the unmanned aircraft.

**Unpiloted Aerial Vehicle (UAV):** An aircraft without a pilot physically onboard – Generally refers only to the actual “flying piece” of the system.

**Unpiloted Aerial System (UAS):** The entire system which flies and supports a UAV, including remote pilot, control station, communications, and the vehicle itself.

**UAS Operator:** The individual in the Air Vehicle Control Station tasked with overall responsibility for operation and safety of the UAS.

**UNPROFOR:** The United Nations Protection Force in the Former Yugoslavia.



REPORT DOCUMENTATION PAGE											
<b>1. Recipient's Reference</b>	<b>2. Originator's References</b> STO-TR-HFM-184 AC/323(HFM-184)TP/475	<b>3. Further Reference</b> ISBN 978-92-837-0174-3	<b>4. Security Classification of Document</b> UNCLASSIFIED/ UNLIMITED								
<b>5. Originator</b> Science and Technology Organization North Atlantic Treaty Organization BP 25, F-92201 Neuilly-sur-Seine Cedex, France											
<b>6. Title</b> Safe Ride Standards for Casualty Evacuation Using Unmanned Aerial Vehicles											
<b>7. Presented at/Sponsored by</b> This Report documents the findings of Task Group HFM-184 (2009 – 2012), which investigated the possibility and acceptability of casualty evacuation using Unmanned Aerial Vehicles (UAVs).											
<b>8. Author(s)/Editor(s)</b> Multiple			<b>9. Date</b> December 2012								
<b>10. Author's/Editor's Address</b> Multiple			<b>11. Pages</b> 154								
<b>12. Distribution Statement</b> There are no restrictions on the distribution of this document. Information about the availability of this and other STO unclassified publications is given on the back cover.											
<b>13. Keywords/Descriptors</b> <table border="0" style="width: 100%;"> <tr> <td style="width: 50%;">Aeromedical evacuation</td> <td style="width: 50%;">Medical evacuation</td> </tr> <tr> <td>CASEVAC</td> <td>Operational aviation medicine</td> </tr> <tr> <td>Casualty evacuation</td> <td>Safety standards</td> </tr> <tr> <td>MEDEVAC</td> <td>Unpiloted aerial vehicles</td> </tr> </table>				Aeromedical evacuation	Medical evacuation	CASEVAC	Operational aviation medicine	Casualty evacuation	Safety standards	MEDEVAC	Unpiloted aerial vehicles
Aeromedical evacuation	Medical evacuation										
CASEVAC	Operational aviation medicine										
Casualty evacuation	Safety standards										
MEDEVAC	Unpiloted aerial vehicles										
<b>14. Abstract</b> <p>The use of Unmanned Aerial Vehicles (UAVs) has dramatically increased in recent years, and they are now being developed and used for many purposes beyond the ISTAR (Intelligence, Surveillance, Targeting and Reconnaissance) functions for which they are most well known. Since studies are now underway in the use of these vehicles for logistics purposes, the question has arisen as to whether they could be used for Casualty Evacuation (CASEVAC). The HFM-184 Task Group has carefully considered operational, clinical, ethical, and legal aspects of this question, and has determined that the use of UAVs for casualty evacuation can be justified and may be potentially beneficial for the casualty under carefully-defined circumstances. The RTG, initially sceptical, now considers that UAVs in the casualty evacuation role are a potentially viable modality, the development of which should be encouraged.</p>											







BP 25  
F-92201 NEUILLY-SUR-SEINE CEDEX • FRANCE  
Télécopie 0(1)55.61.22.99 • E-mail [mailbox@cs0.nato.int](mailto:mailbox@cs0.nato.int)



**DIFFUSION DES PUBLICATIONS**  
**STO NON CLASSIFIEES**

Les publications de l'AGARD et de la STO peuvent parfois être obtenues auprès des centres nationaux de distribution indiqués ci-dessous. Si vous souhaitez recevoir toutes les publications de la STO, ou simplement celles qui concernent certains Panels, vous pouvez demander d'être inclus soit à titre personnel, soit au nom de votre organisation, sur la liste d'envoi.

Les publications de la STO et de l'AGARD sont également en vente auprès des agences de vente indiquées ci-dessous.

Les demandes de documents STO ou AGARD doivent comporter la dénomination « STO » ou « AGARD » selon le cas, suivi du numéro de série. Des informations analogues, telles que le titre et la date de publication sont souhaitables.

Si vous souhaitez recevoir une notification électronique de la disponibilité des rapports de la STO au fur et à mesure de leur publication, vous pouvez consulter notre site Web (<http://www.sto.nato.int/>) et vous abonner à ce service.

## CENTRES DE DIFFUSION NATIONAUX

### ALLEMAGNE

Streitkräfteamt / Abteilung III  
Fachinformationszentrum der Bundeswehr (FIZBw)  
Gorch-Fock-Straße 7, D-53229 Bonn

### BELGIQUE

Royal High Institute for Defence – KHID/IRSD/RHID  
Management of Scientific & Technological Research  
for Defence, National STO Coordinator  
Royal Military Academy – Campus Renaissance  
Renaissancelaan 30, 1000 Bruxelles

### CANADA

DSIGRD2 – Bibliothécaire des ressources du savoir  
R et D pour la défense Canada  
Ministère de la Défense nationale  
305, rue Rideau, 9<sup>e</sup> étage  
Ottawa, Ontario K1A 0K2

### DANEMARK

Danish Acquisition and Logistics Organization (DALO)  
Lautrupbjerg 1-5, 2750 Ballerup

### ESPAGNE

SDG TECIN / DGAM  
C/ Arturo Soria 289  
Madrid 28033

### ESTONIE

Estonian Ministry of Defence  
Estonian National Coordinator for NATO STO  
Sakala 1, Tallinn 15094

### ETATS-UNIS

NASA Center for AeroSpace Information (CASI)  
7115 Standard Drive  
Hanover, MD 21076-1320

### FRANCE

O.N.E.R.A. (ISP)  
29, Avenue de la Division Leclerc  
BP 72, 92322 Châtillon Cedex

### GRECE (Correspondant)

Defence Industry & Research General  
Directorate, Research Directorate  
Fakinos Base Camp, S.T.G. 1020  
Holargos, Athens

### HONGRIE

Hungarian Ministry of Defence  
Development and Logistics Agency  
P.O.B. 25, H-1885 Budapest

### ITALIE

General Secretariat of Defence and  
National Armaments Directorate  
5<sup>th</sup> Department – Technological  
Research  
Via XX Settembre 123, 00187 Roma

### LUXEMBOURG

Voir Belgique

### NORVEGE

Norwegian Defence Research  
Establishment, Attn: Biblioteket  
P.O. Box 25  
NO-2007 Kjeller

### PAYS-BAS

Royal Netherlands Military  
Academy Library  
P.O. Box 90.002  
4800 PA Breda

### POLOGNE

Centralna Biblioteka Wojskowa  
ul. Ostrobramska 109  
04-041 Warszawa

### PORTUGAL

Estado Maior da Força Aérea  
SDFA – Centro de Documentação  
Alfragide, P-2720 Amadora

### REPUBLIQUE TCHEQUE

LOM PRAHA s. p.  
o. z. VTÚLaPVO  
Mladoboleslavská 944  
PO Box 18  
197 21 Praha 9

### ROUMANIE

Romanian National Distribution  
Centre  
Armaments Department  
9-11, Drumul Taberei Street  
Sector 6  
061353, Bucharest

### ROYAUME-UNI

Dstl Knowledge and Information  
Services  
Building 247  
Porton Down  
Salisbury SP4 0JQ

### SLOVAQUIE

Akadémia ozbrojených síl gen.  
M.R. Štefánika, Distribučné a  
informačné stredisko STO  
Demánová 393, Liptovský Mikuláš 6  
031 06

### SLOVENIE

Ministry of Defence  
Central Registry for EU and  
NATO  
Vojkova 55  
1000 Ljubljana

### TURQUIE

Milli Savunma Bakanlığı (MSB)  
ARGE ve Teknoloji Dairesi  
Başkanlığı  
06650 Bakanlıklar  
Ankara

## AGENCES DE VENTE

**NASA Center for AeroSpace  
Information (CASI)**  
7115 Standard Drive  
Hanover, MD 21076-1320  
ETATS-UNIS

**The British Library Document  
Supply Centre**  
Boston Spa, Wetherby  
West Yorkshire LS23 7BQ  
ROYAUME-UNI

**Canada Institute for Scientific and  
Technical Information (CISTI)**  
National Research Council Acquisitions  
Montreal Road, Building M-55  
Ottawa K1A 0S2, CANADA

Les demandes de documents STO ou AGARD doivent comporter la dénomination « STO » ou « AGARD » selon le cas, suivie du numéro de série (par exemple AGARD-AG-315). Des informations analogues, telles que le titre et la date de publication sont souhaitables. Des références bibliographiques complètes ainsi que des résumés des publications STO et AGARD figurent dans le « NTIS Publications Database » (<http://www.ntis.gov>).



BP 25

F-92201 NEUILLY-SUR-SEINE CEDEX • FRANCE  
Télécopie 0(1)55.61.22.99 • E-mail [mailbox@cs0.nato.int](mailto:mailbox@cs0.nato.int)



## DISTRIBUTION OF UNCLASSIFIED STO PUBLICATIONS

AGARD & STO publications are sometimes available from the National Distribution Centres listed below. If you wish to receive all STO reports, or just those relating to one or more specific STO Panels, they may be willing to include you (or your Organisation) in their distribution.

STO and AGARD reports may also be purchased from the Sales Agencies listed below.

Requests for STO or AGARD documents should include the word 'STO' or 'AGARD', as appropriate, followed by the serial number. Collateral information such as title and publication date is desirable.

If you wish to receive electronic notification of STO reports as they are published, please visit our website (<http://www.sto.nato.int/>) from where you can register for this service.

### NATIONAL DISTRIBUTION CENTRES

#### BELGIUM

Royal High Institute for Defence – KHID/IRSD/RHID  
Management of Scientific & Technological Research  
for Defence, National STO Coordinator  
Royal Military Academy – Campus Renaissance  
Renaissancelaan 30  
1000 Brussels

#### CANADA

DRDKIM2 – Knowledge Resources Librarian  
Defence R&D Canada  
Department of National Defence  
305 Rideau Street, 9<sup>th</sup> Floor  
Ottawa, Ontario K1A 0K2

#### CZECH REPUBLIC

LOM PRAHA s. p.  
o. z. VTÚLaPVO  
Mladoboleslavská 944  
PO Box 18  
197 21 Praha 9

#### DENMARK

Danish Acquisition and Logistics Organization  
(DALO)  
Lautrupbjerg 1-5  
2750 Ballerup

#### ESTONIA

Estonian Ministry of Defence  
Estonian National Coordinator for NATO STO  
Sakala 1, Tallinn 15094

#### FRANCE

O.N.E.R.A. (ISP)  
29, Avenue de la Division Leclerc  
BP 72, 92322 Châtillon Cedex

#### GERMANY

Streitkräfteamt / Abteilung III  
Fachinformationszentrum der Bundeswehr (FIZBw)  
Gorch-Fock-Straße 7  
D-53229 Bonn

#### GREECE (Point of Contact)

Defence Industry & Research General  
Directorate, Research Directorate  
Fakinos Base Camp, S.T.G. 1020  
Holargos, Athens

#### HUNGARY

Hungarian Ministry of Defence  
Development and Logistics Agency  
P.O.B. 25, H-1885 Budapest

#### ITALY

General Secretariat of Defence and  
National Armaments Directorate  
5<sup>th</sup> Department – Technological  
Research  
Via XX Settembre 123, 00187 Roma

#### LUXEMBOURG

See Belgium

#### NETHERLANDS

Royal Netherlands Military  
Academy Library  
P.O. Box 90.002  
4800 PA Breda

#### NORWAY

Norwegian Defence Research  
Establishment, Attn: Biblioteket  
P.O. Box 25  
NO-2007 Kjeller

#### POLAND

Centralna Biblioteka Wojskowa  
ul. Ostrobramska 109  
04-041 Warszawa

#### PORTUGAL

Estado Maior da Força Aérea  
SDFA – Centro de Documentação  
Alfragide, P-2720 Amadora

#### ROMANIA

Romanian National Distribution  
Centre  
Armaments Department  
9-11, Drumul Taberei Street  
Sector 6, 061353, Bucharest

#### SLOVAKIA

Akadémia ozbrojených síl gen.  
M.R. Štefánika, Distribučné a  
informačné stredisko STO  
Demánová 393, Liptovský Mikuláš 6  
031 06

#### SLOVENIA

Ministry of Defence  
Central Registry for EU & NATO  
Vojkova 55  
1000 Ljubljana

#### SPAIN

SDG TECIN / DGAM  
C/ Arturo Soria 289  
Madrid 28033

#### TURKEY

Milli Savunma Bakanlığı (MSB)  
ARGE ve Teknoloji Dairesi  
Başkanlığı  
06650 Bakanlıklar – Ankara

#### UNITED KINGDOM

Dstl Knowledge and Information  
Services  
Building 247  
Porton Down  
Salisbury SP4 0JQ

#### UNITED STATES

NASA Center for AeroSpace  
Information (CASI)  
7115 Standard Drive  
Hanover, MD 21076-1320

### SALES AGENCIES

**NASA Center for AeroSpace  
Information (CASI)**  
7115 Standard Drive  
Hanover, MD 21076-1320  
UNITED STATES

**The British Library Document  
Supply Centre**  
Boston Spa, Wetherby  
West Yorkshire LS23 7BQ  
UNITED KINGDOM

**Canada Institute for Scientific and  
Technical Information (CISTI)**  
National Research Council Acquisitions  
Montreal Road, Building M-55  
Ottawa K1A 0S2, CANADA

Requests for STO or AGARD documents should include the word 'STO' or 'AGARD', as appropriate, followed by the serial number (for example AGARD-AG-315). Collateral information such as title and publication date is desirable. Full bibliographical references and abstracts of STO and AGARD publications are given in "NTIS Publications Database" (<http://www.ntis.gov>).