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Original title on 712 A/B: Military SpacePlane: Ground Operations Model

Revised title: ____________________________________________________________

Presented in (input and Bold one): (WG_05, CG__, Special Session ____, Poster, Demo, or Tutorial):

This presentation is believed to be:
UNCLASSIFIED AND APPROVED FOR PUBLIC RELEASE

Wright-Patterson AFB, Ohio Unclassified ALMC Fort Lee, Virginia
Military SpacePlane: Ground Operations Model

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Wright Patterson Air Force Base, Ohio

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73rd MORS Symposium
United States Military Academy, West Point, New York
21 – 23 June 2005
**1. REPORT DATE**  
30 SEP 2005  

**2. REPORT TYPE**  
N/A  

**3. DATES COVERED**  
-  

**4. TITLE AND SUBTITLE**  
Military Space Plane: Ground Operations Model  

**5a. CONTRACT NUMBER**  
-  

**5b. GRANT NUMBER**  
-  

**5c. PROGRAM ELEMENT NUMBER**  
-  

**5d. PROJECT NUMBER**  
-  

**5e. TASK NUMBER**  
-  

**5f. WORK UNIT NUMBER**  
-  

**6. AUTHOR(S)**  
Air Force Research Lab / Air Vehicle Control Directorate Wright Patterson Air Force Base, Ohio  

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**  
Air Force Research Lab / Air Vehicle Control Directorate Wright Patterson Air Force Base, Ohio  

**8. PERFORMING ORGANIZATION REPORT NUMBER**  
-  

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**  
-  

**10. SPONSOR/MONITOR’S ACRONYM(S)**  
-  

**11. SPONSOR/MONITOR’S REPORT NUMBER(S)**  
-  

**12. DISTRIBUTION/AVAILABILITY STATEMENT**  
Approved for public release, distribution unlimited  

**13. SUPPLEMENTARY NOTES**  

**14. ABSTRACT**  
-  

**15. SUBJECT TERMS**  
-  

**16. SECURITY CLASSIFICATION OF:**  

<table>
<thead>
<tr>
<th>a. REPORT</th>
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**17. LIMITATION OF ABSTRACT**  
UU  

**18. NUMBER OF PAGES**  
28  

**19a. NAME OF RESPONSIBLE PERSON**  
-  

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*Standard Form 298 (Rev. 8-98)  
Prescribed by ANSI Std Z39-18*
Introduction

- MSP Ground Operations
- Problem Statement
- Modeling Considerations
- Problem Solving Approach
- Venture Evaluation Review Technique
- System Data & Analysis
- Findings & Recommendations
- Summary & POC Information
Air Vehicles Directorate

Vision

Provide the Best Air Vehicle Technologies for Aerospace Dominance

NEAR

FAR

MID

Strike UAVs
Technology Insertion
Long Range Strike
Persistent ISR
Space Operations Vehicle
Directed Energy Integration
Advanced Mobility

Wright-Patterson AFB, Ohio
Unclassified
ALMC Fort Lee, Virginia
Directorate Mission

- Plans, formulates, and directs science & technology research for military air vehicles exploration and advanced technology development
- Orchestrates/executes technology developments in aeronautical sciences, control sciences, and aerospace structures
- Integrates systems level air vehicle technologies with other AFRL directorates. Provides technical support for aerospace systems integration
- Orchestrates technology development with other DOD and national laboratories, industries, universities, NASA, FAA, NATO, and other foreign research organizations
MSP
Military Space Plane

MSP is a reusable space taxi for carrying payloads into and from space. A spacecraft that embodies “aircraft-like” characteristics of current air vehicle platforms.

- Space Control
- Force Enhancement
- Space Support
- Force Applications

- Reusable space delivery and mission operation system
- Timely delivery of mission assets to and from space
- Multi-mission capable with interchangeable payloads
- Short-cycle, rapid mission turn around time
MSP Modules

Three Components

1. Space Operations Vehicle (SOV) Reusable Booster

2. Space Maneuver Vehicle (SMV) and Various Upper Stages

3. Various Operational and Space Mission Payloads
Operationally Response Spacelift systems must be available and dependable... They must also be reliable, supportable, maintainable and robust enough to generate required mission rates... capable of meeting required turnaround-times

Mission Need Statement for Operationally Responsive Spacelift (20 Dec 01)

Need mid/far-term SS capabilities including robust and responsive space lift, rapid satellite configuration/on-orbit initialization; provide quick-turn, on-demand, assured space access for time-sensitive military operations (re-position or boost on-orbit assets)

AF Space Command Strategic Master Plan Space Support Roadmap (1 Oct 03)

During periods of war [provide] ... sortie rate at least .33 sorties per day with an objective of .50 sorties per day; surge; .50 sorties per day with an objective of 1.0 sorties per day. During periods of war or exercise [provide] ... turn times of 18 hours with an objective of 12 hours; surge of 12 hours with objective of 8 hours.

Systems Requirements Document for Military SpacePlane System (12 Feb 01)
Problem Statement

A key element in space sortie generation continues to be the ability to reduce ground operations turnaround times.

Problem Statement

While there is data for real systems, there is little basic research on ground operations for experimental military spacelift vehicles. Turnaround information shortfall applies to processes based on engineering designs and on estimated data useful to a spacelift operation center (SOC) responsible for command and control of spacelift platforms.
SAVMOS
Space Access Vehicles Mission & Operations Simulation

Mission/Decision Support Tools
• Flight Controls
• Flight Dynamics
• System Status
• Visualization

Addressing Ground Operations

MSP Launch
Mission Preflight
GUI
Mission Operations
Mission Re-Entry
Recover & Recycle

Flight Operations

Ground Operations

Wright-Patterson AFB, Ohio
ALMC Fort Lee, Virginia
# Vehicle Comparisons

<table>
<thead>
<tr>
<th>System</th>
<th>Space Shuttle</th>
<th>SpaceShipOne</th>
<th>X-37 Vehicle</th>
<th>B-2 Bomber</th>
<th>MSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mission</td>
<td>Operational</td>
<td>Experimental</td>
<td>Experimental</td>
<td>Operational</td>
<td>TBD</td>
</tr>
<tr>
<td>Crew</td>
<td>Manned</td>
<td>Manned</td>
<td>Unmanned</td>
<td>Manned</td>
<td>Unmanned</td>
</tr>
<tr>
<td>Size &amp; weight (Payload)</td>
<td>Large</td>
<td>Small</td>
<td>Small</td>
<td>Large</td>
<td>Variable</td>
</tr>
<tr>
<td>Sortie Rate</td>
<td>180+ days</td>
<td>2 &lt; weeks</td>
<td>N/A</td>
<td>8 &lt; hours</td>
<td>Goal: 8 &lt; hrs</td>
</tr>
</tbody>
</table>
Ground Operations
(Mission Ops)

Large and Manpower Intensive

Notional SAVMOS Facility & Crew Size

- Minimized crew size (operational manning)
- Reduced facility size (footprint)
- Reduced cost
Major Ground Operation Activities

Mission Return Phase 1
- Safe-making & moving
- Health assessment
- Post-mission Inspecting
- Payload removal
- 3 phase maintenance
- Flight Storage

Sortie Generation Phase 2
- Preflight ops checks
- Payload instantiation
- Connections & assembly
- Transport to pad
- Fueling operations
- Pre-launch preparation
Modeling Considerations

- Which operations to model (sequence major event)
- Size and scope (Fidelity) of model
- Sources of modeling information (B-2, Cape, Dryden)
- Comparative space-air data
- Data types and acquisition
- Criteria for computer model selection
- Model construction of ground operations
- Experiments with Ground Ops simulation
- Development of tools and algorithms
Levels and Scope of Modeling

• Spaceport Level
  – Entire space facility (all operations)
  – Every aspect of resources (A to Z)
  – Continuous flow (multi-ship operations)

• Operations Level
  – Mission operations vs. ground operations
  – Single cyclic flow of MSP(s)
  – Resources dedicated to sortie generation

• Engineering Level
  – Single ship high resolution activities
  – Craftsman level of operations
  – Detailed estimates (e.g., tile replacement)
Problem Solving Approach

- Perform phenomena research
- Determine processes and data sources
- Build a conceptual spacelift turnaround model
- Research COTS/GOTS software

- Select software and data for simulation
- Experiment with the ground ops simulation
- Analyze results and seek validation
- Refine the model and further develop tools
One Ground Operations Modeling Approach

Dr. George Huntley
Army Logistics Management College
ALMC
Army Logistics Management College

- Trains US civilians, military, and US allies
- Major teaching subjects and consulting areas:
  - Systems Engineering (ORSA/MAC-I, Cont. Education, STS)
  - Logistics Courses (CLC3....)
  - Defense Acquisition Training (Mil. Acquisition Mgt)
  - Military Operations Research/Systems Analysis
  - Decision Risk Analysis for Engineers
- Resident, Onsite, Web and DL Instruction
- 50th Anniversary in 2004
- Trained over quarter-million DoD students

ALMC at Fort Lee, Virginia (www.almc.army.mil)
VERT is a network computer simulation “Engine”

- Builds greatly upon PERT/CPM but is stochastic
- Developed by Gerald L. Moeller at US Army’s Rock Island Arsenal, Illinois & others since 1970s
- Used for describing & analyzing new & risky projects
- Uses time, cost, performance, & probabilities to evaluate alternatives
- Free for US Govt use & easy to Learn
General VERT Use

Great for analyzing small to moderately complex projects

- Historically used to
  - Develop new weapons systems
  - Generate independent cost estimates
  - Effects of chemical demilitarization
  - Estimate logistics problems of simultaneously fighting several limited world conflicts
  - Plan reactivation of “Mothballed” facilities
  - Other efforts (reliability, design, safety)
VERT Strengths & Limitations

• **Strengths**
  – Graphical formulation converts to arcs and nodes with data
  – Easy to learn, formulate model, and instantiate
  – Provides quick turn simulation runs
  – Automatically provides useful statistical output
  – Price is A-OK, ALMC is sponsor

• **Limitations**
  – Can be unwieldy with gigantic projects
  – NO “looping back” to previous part of network
  – PC Version 3.7 limited to 350 arcs/200 nodes/1000 iterations
  – Only 20 internal/10 terminal node, 20 slack histograms
  – PC Version needs VV&A on queue and time phasing
  – Minimal “user friendly” features (DOS like)
VERT 101

Arcs are Activities

Tying your shoe

Prob of success

Arcs not Orcs

From Node

To Node

Time(T)/Cost(C)/Performance(P) Estimates

Nodes are conditional branch points or decision logic points

Start
Terminate
And
Or
Compare T/C/P
Waiting Queue

Some Example VERT Nodes

Wright-Patterson AFB, Ohio
Unclassified
ALMC Fort Lee, Virginia
**Post-Landing**

- Vehicle made safe
- Vehicle moved to safe area
- Vehicle made safe
- Move vehicle to MX bay
- Unscheduled MX
- Timed, count, instance MX
- STD Systems
- STD Subsystems
- Inspect item MX
- Place in readiness bay
- Extended maintenance
- Correct/Re-Inspect/bay
- Depot required MX

**Durations**

- **Dtime:** Indicates the duration of the process.
- **Dperf:** Indicates the performance duration.
- **Dcost:** Indicates the cost duration.

- **P(s)=.95** indicates a probability of success.
Pre-Launch

Transport SMV to preflight area
Dtime Tri: 20-30-45
Dperf Tri: 40-60-90
Dcost Tri: 18-25-38

Position in hangar clean room
Dtime Tri: 7-10-20
Dperf Tri: 15-20-40
Dcost Tri: 30-50-63

Power-off check list
P(s)=.99

Pass checkout for power-off
Dtime Tri: 45-60-75
Dperf Tri: 90-120-150
Dcost Tri: 75-100-150

Remove/replace power-off failed items

Load SMV onto transport
Dtime Tri: 45-60-120
Dperf Tri: 225-300-600
Dcost Tri: 95-125-250

Mount on RLV Mate umbilical
Dtime Tri: 45-60-75
Dperf Tri: 135-180-225
Dcost Tri: 60-75-95

Prepare payload
Dtime Tri: 45-60-120
Dperf Tri: 225-300-600
Dcost Tri: 95-125-250

Install Payload
Dtime Tri: 45-60-120
Dperf Tri: 225-300-600
Dcost Tri: 95-125-250

Mount on RLV Mate umbilical
Dtime Tri: 45-60-75
Dperf Tri: 135-180-225
Dcost Tri: 60-75-95

Load propellants
Dtime Tri: 30-45-60
Dperf Tri: 30-90-120
Dcost Tri: 25-38-50

Final system checks
P(s)=.98

Pass final system check
Launch
Dtime Tri: 10-15-20
Dperf Tri: 20-30-40
Dcost Tri: 60-90-125

Fix system
Dtime Tri: 45-60-75
Dperf Tri: 135-180-225
Dcost Tri: 60-90-125

Final system checks
P(s)=.98

Pass final system check
Launch
Dtime Tri: 10-15-20
Dperf Tri: 20-30-40
Dcost Tri: 60-90-125

Fix system
Dtime Tri: 45-60-75
Dperf Tri: 135-180-225
Dcost Tri: 60-90-125

Final system checks
P(s)=.98

Pass final system check
Launch
Dtime Tri: 10-15-20
Dperf Tri: 20-30-40
Dcost Tri: 60-90-125

Fix system
Dtime Tri: 45-60-75
Dperf Tri: 135-180-225
Dcost Tri: 60-90-125
## Network Results

<table>
<thead>
<tr>
<th>Post-Return</th>
<th>Arc/Nodes</th>
<th>Key Probabilities (Notional)</th>
<th>Hour</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sch/Unsch MX</td>
<td>21 Activities</td>
<td>.95 De-fuel ops</td>
<td>4.45 *</td>
<td>98</td>
</tr>
<tr>
<td>MX Delay</td>
<td>15 Decision Points</td>
<td>.99 No depot MX</td>
<td>.95 Cert. inspection</td>
<td>7.86 *</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pre-Launch</th>
<th>Arc/Nodes</th>
<th>Key Probabilities (Notional)</th>
<th>Hour</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation, test, &amp; payload</td>
<td>25 Activities</td>
<td>.95 Power off check</td>
<td>.95 Power on check</td>
<td>.99 Computer check</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Post-Return thru Pre-Launch</th>
<th>Arc/Nodes</th>
<th>Key Probabilities (Notional)</th>
<th>Hour</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>All activities</td>
<td>47 Activities</td>
<td>Same probabilities as above</td>
<td>16.6 *</td>
<td>100</td>
</tr>
</tbody>
</table>

* Results are from Notional Inputs
Findings & Recommendations

• Findings
  – Large amount of time devoted to moving, racking, and stacking
  – Small Prob of failure results in dramatic decreases in time & cost
  – Payload preparation has to be a parallel activity (racks)
  – Goal is to avoid depot maintenance delays (spares)
  – Estimates employed in this draft are highly optimistic
  – Model assumed unlimited use of working spaceport resources

• Recommendations
  – Continue work on validation of changing processes (TPS, IVHM)
  – Obtain better data on maintenance tests and durations
  – Move to a more sophisticated computer model when spaceport and vehicle operational data becomes available
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