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AUTOMATED AERIAL REFUEL (AAR) TECHNOLOGIES AND CHALLENGES
Delivery Order 0048

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Automated Aerial Refuel (AAR) Technologies and Challenges

AIAA Section Meeting
13 Apr 04

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Presentation Outline

- Background
  - Significance to Air Force
  - AAR Program Key Aspects
  - AAR Project Approach
  - National AAR Team
- Conceptual Design Development Process
  - AAR Process
  - CONOPs and Requirements
- Conceptual Designs
  - Selection Process
  - Conceptual Design Families
- Simulation Development
- AAR’s Future
Significance to Air Force

- Unmanned Aerial Vehicles
  - Extends Range
  - Shortens Response for Time-Critical Targets
  - Maintains In-Theater Presence Using Fewer Assets
  - Deployment with Manned Fighters and Attack Without the Need of Forward Staging Areas

“If we decided to fly them across the ocean, we have to work on things like automatic air refueling” - Gen. John Jumper, USAF, August 2001

- Manned Aircraft
  - Provides Adverse Weather Operations
  - Improves Fueling Efficiency
  - Reduces Pilot Workload
AAR Program Key Aspects

Automating the Receiver
- Demonstrate an Operationally Feasible UAV Refueling Capability
  - Near-Term Focus – Boom/Receptacle Refueling
    - Target was Air Force UAVs
    - Near-Term Refueling

...
AAR Project Approach

Heavy User Involvement From AMC/XPR, ACC/DRZ, ASC/FB, And DARPA
National AAR Team

AFRL/HE
AFRL/IN
AFRL/N

AMC/XP
Naval
NORTHROP GRUMMAN

SynGenics

Boeing

BLACK HAWK

Advanced Information Systems
Conceptual Design Development Process

Top Level Storyboards

Operational Concepts

F-16 Air Refueling Operating Procedures
TO.1-1C-1-3 Air Refueling Manual

Concept Exploration Team

Storyboards With Functions and AAR Components

AAR Components Evaluation

Conceptual Designs
- Navigation Based
- Sensor Based

US Air Force Photo

US Air Force Photo
J-UCAS Mission/AAR
Overview

Generic Communication for
Storyboard Charts

Ground Ops

En Route

Rendezvous

Mission Preparation

Post-Flight

Observation Position

Post-AR Procedures

Contact Position

Disconnect
The AAR Process

Define AAR CONOPS
- AR Tech Orders
- Heavy User Participation
- Mission Story Boards

80 CONOPS Procedures

Define Candidate Technologies
- 35 Technologies Identified to Perform CONOPS

AAR Requirements
- Heavy User Participation
- Four Requirement Groups
  - Performance
  - Safety
  - Cost
  - Integration Into UCAS

54 Requirements

80 CONOPS Procedures

Technologies Down Selected

AAR Conceptual Designs
- 4 Design Families Identified
  - Three Sensor Based
  - One Navigation Based

4 Conceptual Design Families With 14 Variations

IPPD Affordability Evaluation
- Designs Evaluated vs. Requirements
- Two Conceptual Designs Selected
The CONOPs

- Working with ACC & AMC to Develop Conops
- Used F-16 Procedures As Baseline
- Refueling 4-Ship UCAS Packages
- Manned Refueling Procedures

Based AAR Procedures On Current Manned Aircraft Procedure Ensuring Seamless Integration, Ease Transition
Example CONOPs: Contact Position

**Authorized UCAS Stabilizes in Pre-Contact Position**

- Boomer Authorizes UCAS to Contact Position
- Authorized UCAS Stabilizes in Contact Position
- Boomer Plugs UCAS
- UCAS Acknowledges Contact to MCS Operator
- Confirmation of Contact Is Provided to Tanker
- UCAS Maintains Contact Position

**UCAS Takes Fuel**
Overarching User Requirements

- User Relevance Requires:
  - Protect Tanker From Collision With UCASs
  - Identify and Design Most Affordable Solution
    - Consider Impact to Rest of UCAS System of Systems (SoS) Impact
    - Minimal Impact to LO Design
    - Minimize (or Eliminate) Tanker Modifications
  - Minimize Impact to Refueling Mixed Fleet Operation
AAR Requirements: Performance Example

P001B: Refueling Efficiency: Closure to Contact

- UCAV will move smoothly and efficiently from the Precontact Position to the Contact Position upon Boomer authorization.

![Graph showing refueling efficiency over time.]

Time (seconds) from Boomer authorization (to close to contact) until receiver stabilizes in Contact Position. Threshold is the typical time for piloted aircraft.

- 4 Areas
  - Performance
  - Safety
  - Cost
  - Integration

- 54 Requirements

- Developed With Direct Warfighter Involvement

- Derived from Battlefield Requirements and CONOPs
Critical Functions Drive AAR Conceptual Design Selection

- **Strongest Design Drivers Functions (In Order of Priority):**
  - UCAS Ability to Precisely Maneuver Around Tanker
  - UCAS Ability to Perform Rendezvous with Tanker

- **Other Important Functions**
  - Boomer Ability to Immediately Command Break-Away
  - Tanker’s Ability to Determine Range to UCAS in Real Time (Point Parallel Rendezvous)
  - Tanker’s Ability to Communicate with MCS Operator
Precision Positioning System
Accuracy Requirements at Contact

Boom Air-to-Air Refueling Envelope

Note: Distances are for zero azimuth angle

- Refueling Envelope Center
- Goal Envelope
- Threshold Envelope

X Distance - ft
Z Distance - ft

-30 -25 -20 -15
-30 -25 -20 -15
30 35 40 45
30 35 40 45
AAR Conceptual Design Families

Navigation-Based

Advantages:
- Lowest Technical Risk For Initial Capability
- All Weather Capability
- Compatible With Navy Ops
- Simple Vehicle Integration

Disadvantages:
- Requires Tanker Modifications

Sensor Based

Advantages:
- Most Affordable Conceptual Design
- Sensor May Enable Additional UCAS Capabilities

Disadvantages:
- UCAS Vehicle Integration
- Sensor Development Risk
Simulation Development

- Integrated Aerial Refueling R&D Simulation Being Developed
  - Boomer Station
  - UCAS Operator Station
  - Tanker Pilot Cube
  - Other Receiver Stations
- Provides Test Bed for AAR System Development
  - Allows Rapid Prototyping and Early Operator Interactions
  - Helps Develop and Visualize Correct Story Boards
Summary

- Automated Refueling is a Key Capability for UCAS
- Automation Can Provide Significant Improvements in Refueling Capability and Efficiency
- Technology Application to Manned Aircraft
- Automatic Adverse Weather Rendezvous
- Situational Awareness and Collision Avoidance for Simultaneous Multiple Receivers
- AFRL, ASC, AMC, ACC, and DARPA have Teamed With Industry
- Concepts Developed in Desktop Simulation Environment can be Quickly Moved to a Man-In-The-Loop Simulation Environment for Boom, Tanker Pilot, and UAV Controller Evaluations
AAR's Future

- Continue Requirements Development
- Analysis
- Simulation
- Off-Line Simulations
- Real Time "Boomer in the Loop"
- AAR Technology Maturation
- Flight Test
- Gather Sensor Data
- Demonstrate Station Keeping Capability
- Demonstrate Dry/Wet Hookups
- Boom and Receptacle
- Probe and Drogue