

Results of NASA/DARPA Automatic Probe and Drogue Refueling Flight Test



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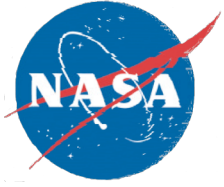
Program Objective

Phase I Objectives: (1 May 2005 - 30 August 2006)

To make one demonstration fully automatic engagement (probe plugging the drogue) between the F-18 and the Omega Air B707 tanker using the Autonomous Airborne Refueling System.

Phase II Objectives: (October 2006 - April 2007)

- Optimal Tuning of AARD Controller
- Evaluate plug performance in a turn
- Autonomous Rendezvous with the tanker
- Improve Video Tracker Performance



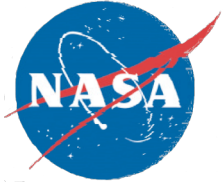
Technical Background

- High Risk Technology
- Technology Demonstration not Development Program
- Low Cost
- Compressed Development Schedule
- Reduced number of test conditions
- Reduced redundancy/ error correction in the system.



Project Timeline

- March 05 Proposal Kickoff Meeting @ DFRC
- 05-05-05 and 05-18-05 Kickoff Meetings
- 07-12-05 System Requirements Review
- 08-30-05 Preliminary Design Review
- 10-19-05 Critical Design Review
- 10-24-06 Risk Reduction Flight
- 03-02-06 Hardware Arrives at Dryden
- 04-04-06 Flight Readiness Review
- 05-18-06 Airworthiness and Flight Safety Review Board
- 06-12-06 Tech Brief (Surrogate Tanker)
- 06-16-06 through 06-29-06 Surrogate Tanker Flights
- 07-06-06 Tech Brief (Omega Tanker)
- 07-11-06 through 08-30-06 Omega Tanker Flights
- 10-1-06 Start of Phase II Flight Program
- 11-17-06 through May 2007 Phase II Flight Tests

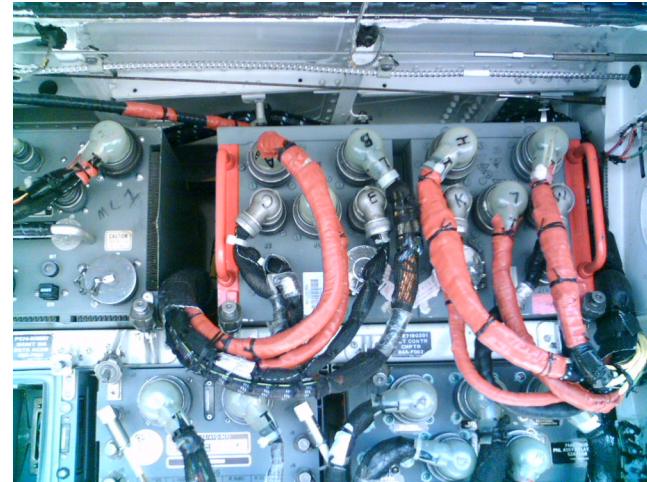


System Architecture

Video Input



Production Support Flight Control Computers



↑ ↑ ↑ Pitch Stick
Roll Stick
Delta Throttle ↑ Rudder =



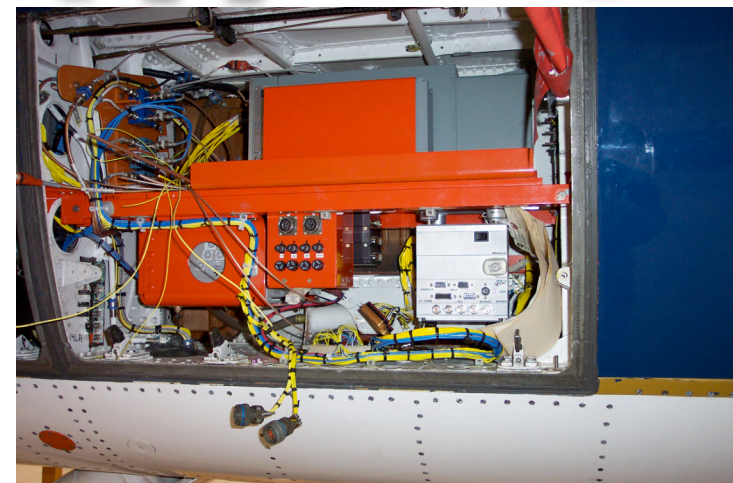
Push Button Display

Command/
Status
Information

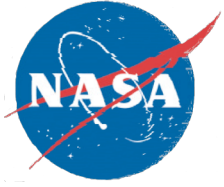


Tanker Pallet

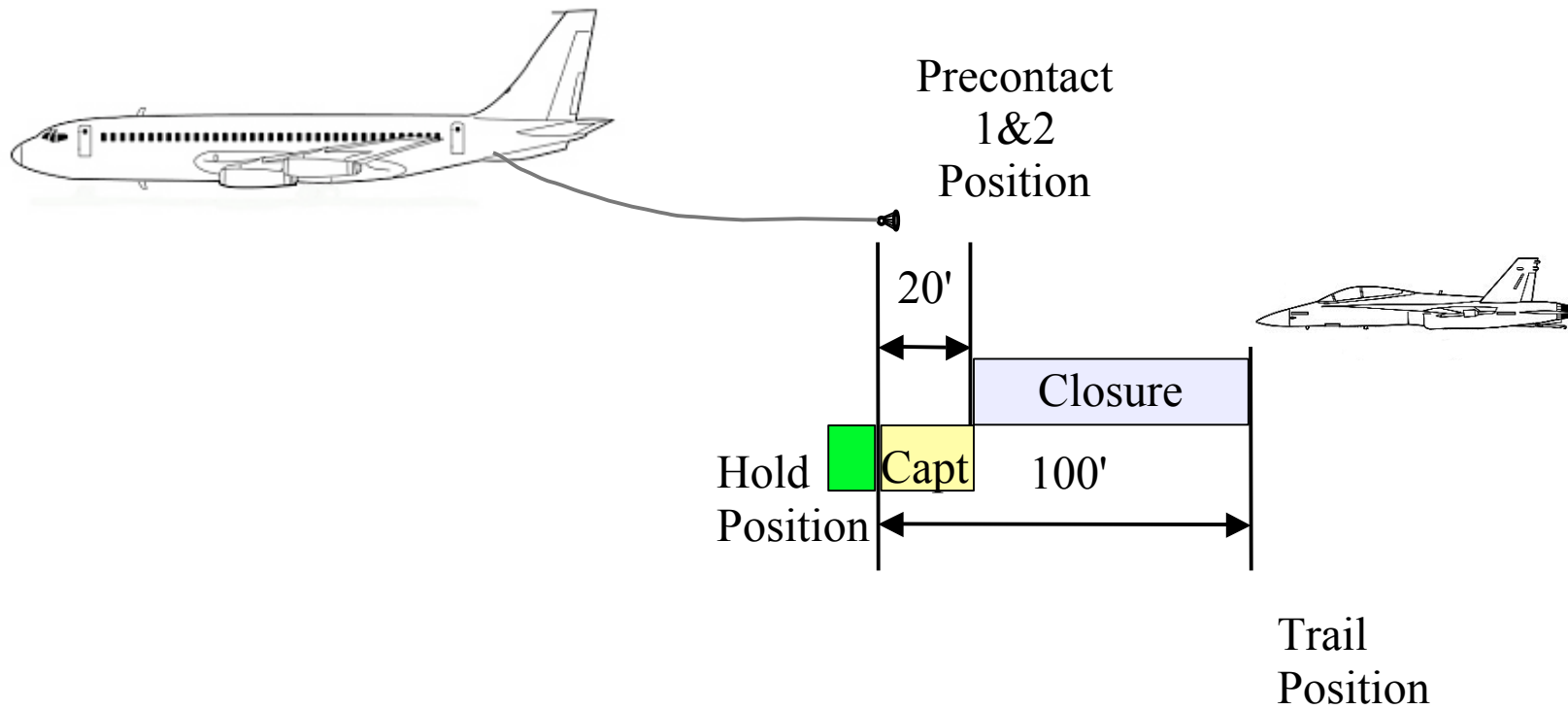
|| Data Link →



Receiver System

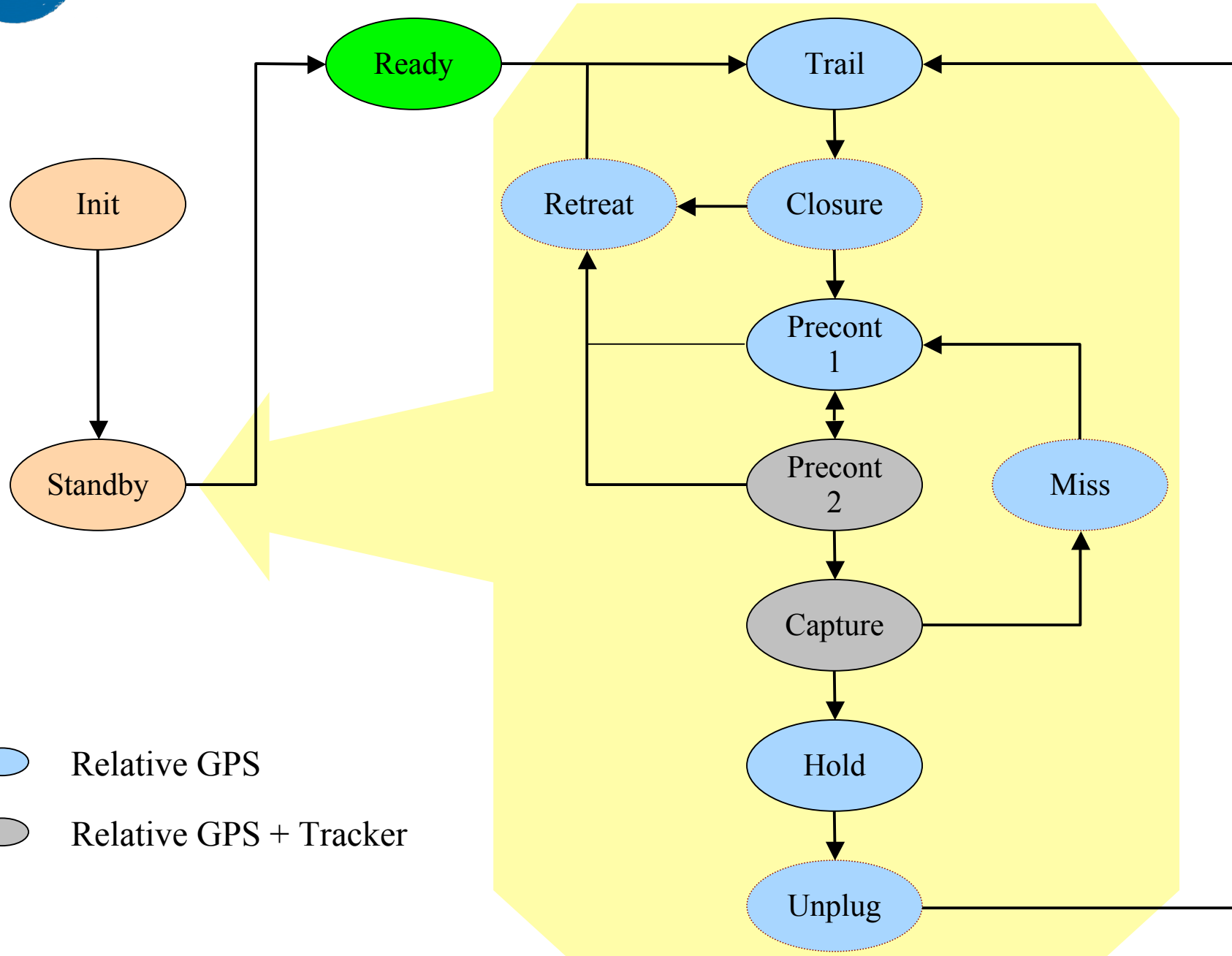


Refueling Geometry





AARD Modes and States





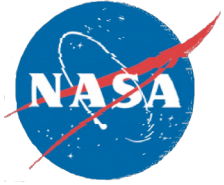
Accuracy Design Targets

➤ **Station Keeping Mode.**

- $\pm 6.5'$ longitudinal position
- $\pm 6.5'$ vertical position
- $\pm 10'$ lateral position

➤ **Capture Mode**

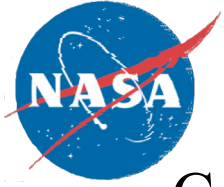
- System must be able to reliably guide/control receiver aircraft within $\pm 11''$ of desired location, in the conditions intended for demonstration, 95% of the time
- Requirement driven by basket dimensions: 32'' outside diameter
- Project pilot estimates plug success rate at 95% if the probe is positioned inside 4'' from outside edge of drogue



Omega Tanker Risk Reduction

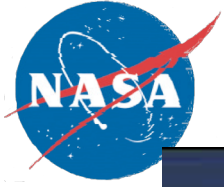
- Approach to plug on left and right drogues using the cockpit and pylon camera
- Tanker pitch/ roll/ yaw maneuvers
- Varying approach rates/ trajectories
- Survey of capture and miss locations on the drogue
- Varying plug attempts at different diameters from the center of the drogue





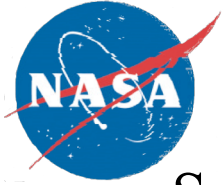
Ground Test Activities

- Cart Testing
 - Evaluated Tanker/ Receiver subsystems and communications
 - Performed Prior to hardware delivery to Dryden
- Simulation Lab testing
 - Performed formal Verification and Validation testing of G&C algorithm
 - Performed failure modes and effects testing
- Hanger Radiation Testing
 - First Integrated systems testing with a stationary aircraft
 - First evaluation of tracker performance
- Combined Systems Testing
 - Plugs out evaluation of the integrated system
 - Evaluation of tracker performance during taxi.



Combined Systems Taxi Test

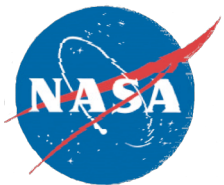




Surrogate Tanker Flights

- Surrogate tanker was used to increase test efficiency
 - Lower cost per hour to fly
 - Easier to schedule.
- Tested engage/ disengage/ reversion modes.
- Commanded Autonomous modes through Precontact 1
- Gathered system performance data using sine and step inputs
- Gathered system performance data for a variety of gains
- Tracked Surrogate tanker through a turn in Trail and Precontact 1

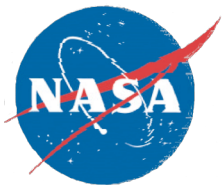




Omega Tanker Flights

- Tested engage/ disengage/ reversion modes.
- Commanded mode transitions through unplug
- Gathered/ tuned the video tracking algorithm.





First Plug Attempt





Second Plug Attempt



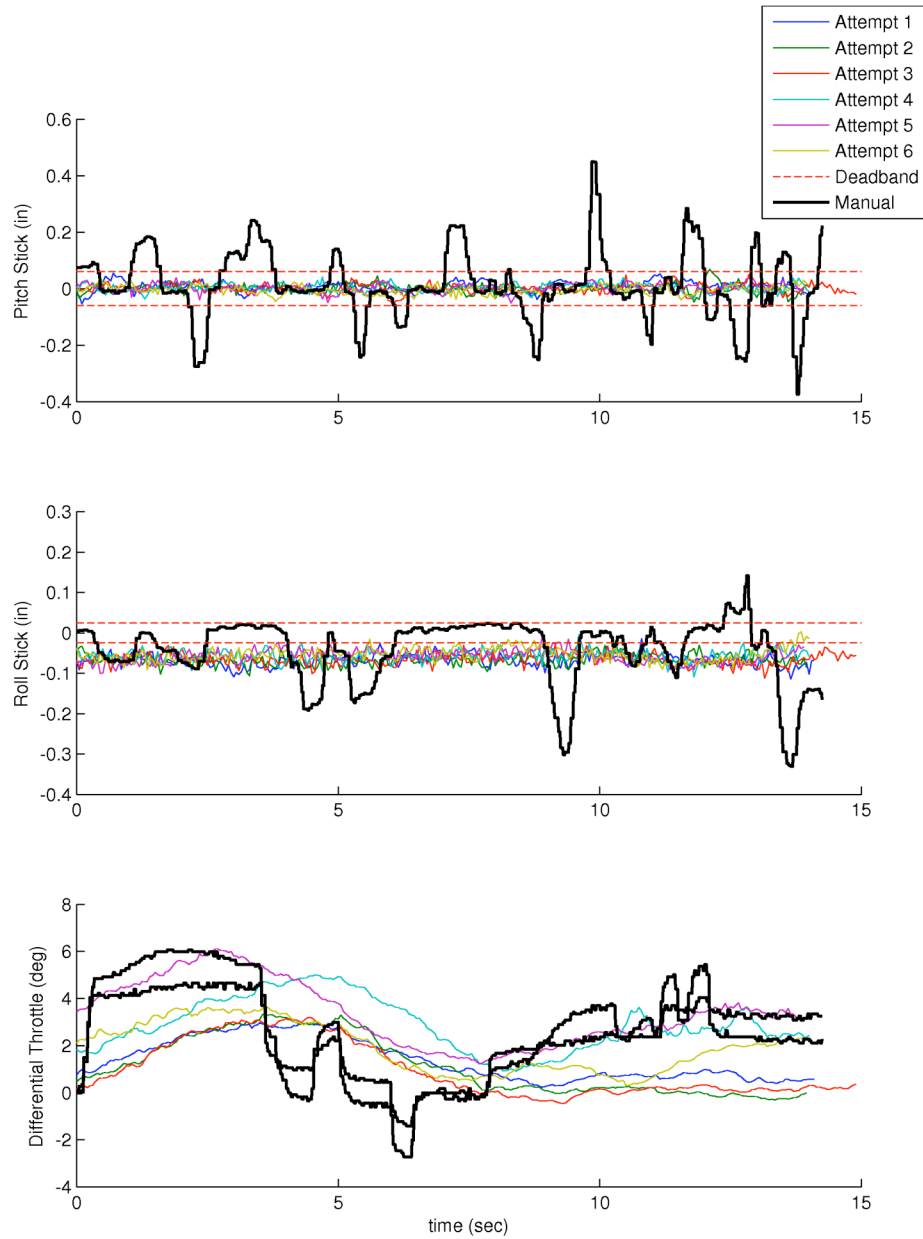


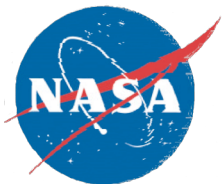
Success





Control Position Comparison





Phase II Flights

- Demonstrated Autonomous Rendezvous to Trail Position
 - 2000 ft trail, 1000 ft low, 500 ft lateral offset
 - 15 to 20 kt closure rate
- Demonstrated Autonomous Plug in a turn
 - 20 Deg Bank turn
 - Achieved a stable hold position in turn
 - Unplug in turn
- Controller and Tracker evaluation/ tuning
 - Have shown improvement in both controller and tracker performance
 - Demonstrated successful plug in mild turbulence





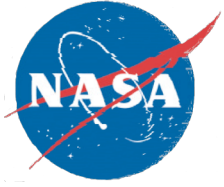
Phase II Plug Performance





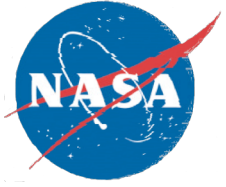
Phase II Plug in a Turn





Summary

- Designed, developed and successfully tested a prototype system to autonomously perform probe to drogue refueling.
- Demonstrated acquisition and tracking capability of the video tracking subsystem.
- Demonstrated autonomous rendezvous capability
- Demonstrated the ability to plug in a turn
- Demonstrated the ability to plug in mild turbulence



Questions?



System Architecture

