VULTURE

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Agenda

DARPA's Charter & Commitment

VULTURE Overview

- Motivation / Vision
- Philosophy / Concept
- Program Objectives and Goals

Technology Areas

Acquisition Strategy

- Program Plan (all phases)
- Source Selection Schedule

Program Solicitation Overview

- BAA (& OTA) Requirements
- Proposal Overview
- Evaluation Process

Summary

Question and Answers

Welcome to VULTURE Industry Day

Mr. Stephen P. Welby
Director, Tactical Technology Office

What is DARPA?

The Defense Advanced Research Projects Agency is the central R&D arm of the Department of Defense with the primary responsibility to conceive, explore, and demonstrate breakthrough system concepts and the most advanced technologies.

What is DARPA’s Mission?

Maintain Superiority

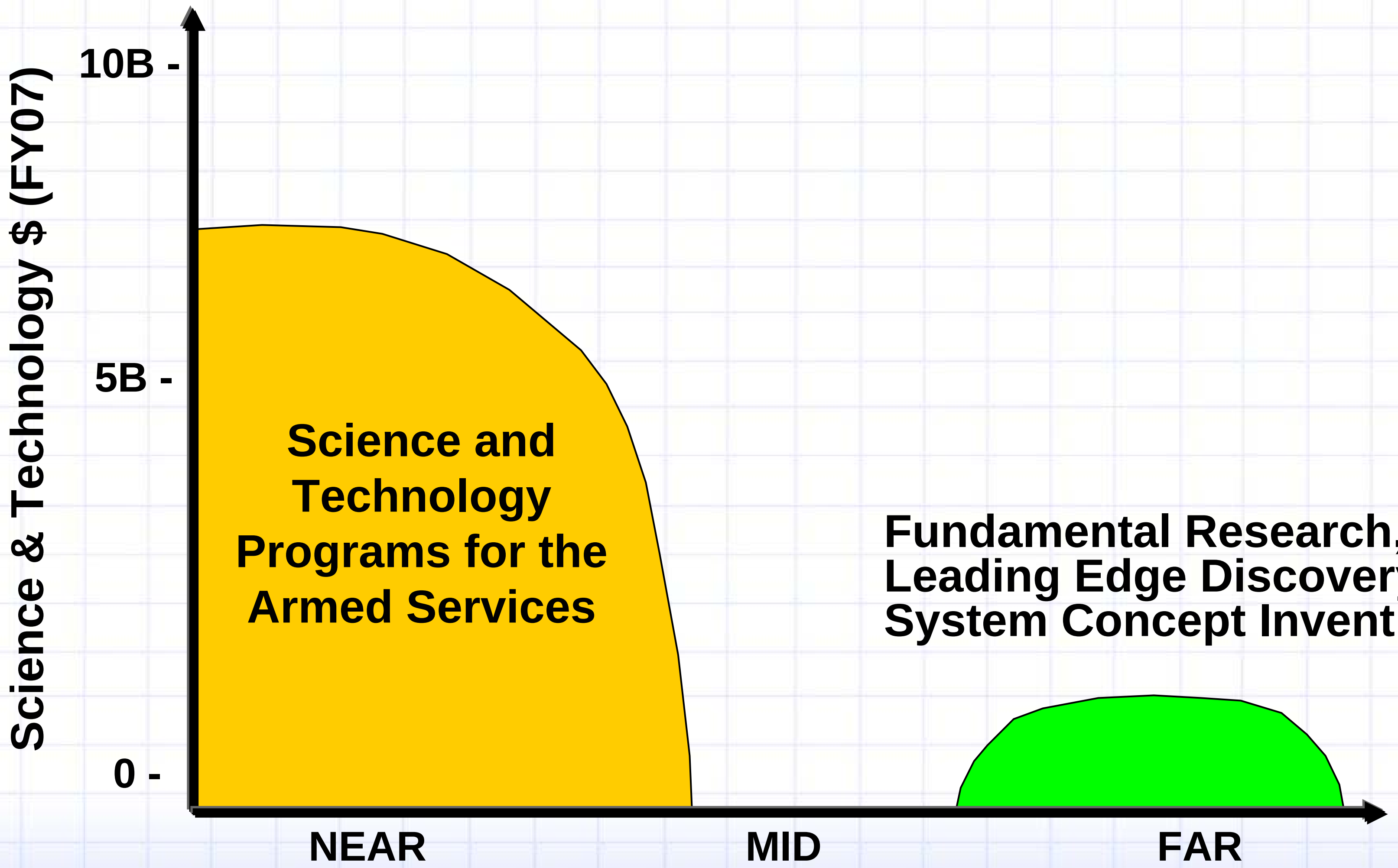
Prevent Surprise

DARPA’s mission is to maintain technological superiority of the US military and prevent technological surprise from harming our national security by sponsoring revolutionary, high-payoff research that bridges the gap between fundamental discoveries and their military use.

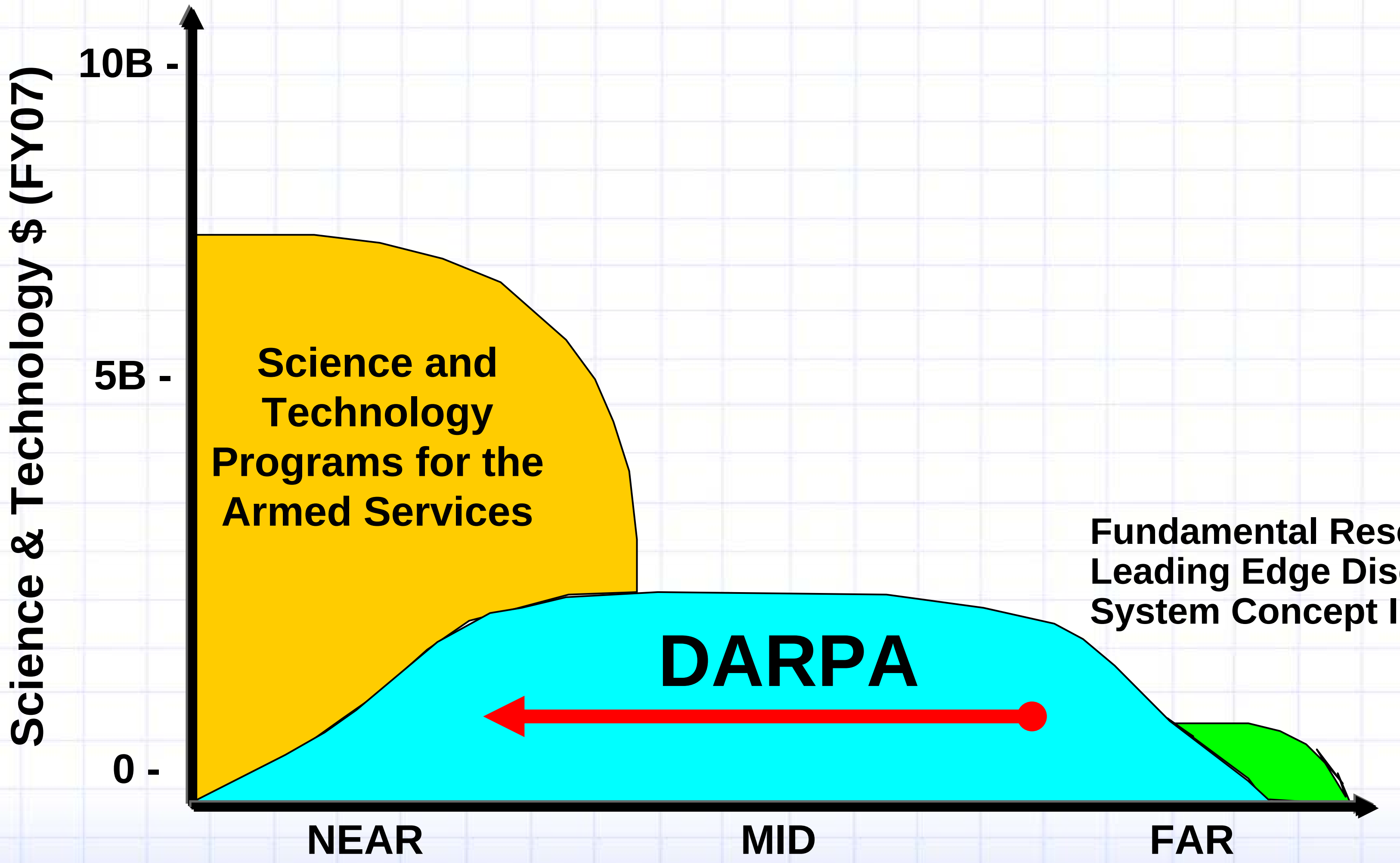
High Risk

High Payoff

DARPA Role in Science and Technology



DARPA Role in Science and Technology



DARPA Accomplishments

Approved for public release; Distribution is unlimited

DARPA Organization

Director, Tony Tether
Deputy Director, Bob Leheny

Tactical Technology
Steve Welby
Steve Walker

- Air/Space/Land/Sea Platforms
- Unmanned Systems
- Space Operations
- Directed Energy Systems
- Precision Strike

Information Exploitation
Bob Tenney
Mark Davis

- Sensors
- Exploitation Systems
- Command & Control

Strategic Technology
Dave Honey
Larry Stotts/Brian Pierce

- Space Sensors/Structures
- Strategic & Tactical Networks
- Information Assurance
- Underground Facility Detection & Characterization
- Chem/Bio Defense
- Maritime Operations

Defense Sciences
Brett Giroir
Barbara McQuiston

- Physical Sciences
- Materials
- Biology
- Mathematics
- Human Effectiveness
- Bio Warfare Defense

Information Processing Technology
Charlie Holland
Barbara Yoon/Chuck Morefield

- Cognitive Systems
- High Productivity Computing Systems
- Language Translation

Microsystems Technology
John Zolper
Dean Collins

- Electronics
- Photonics
- MEMS
- Algorithms
- Integrated Microsystems

TTO Thrust Areas

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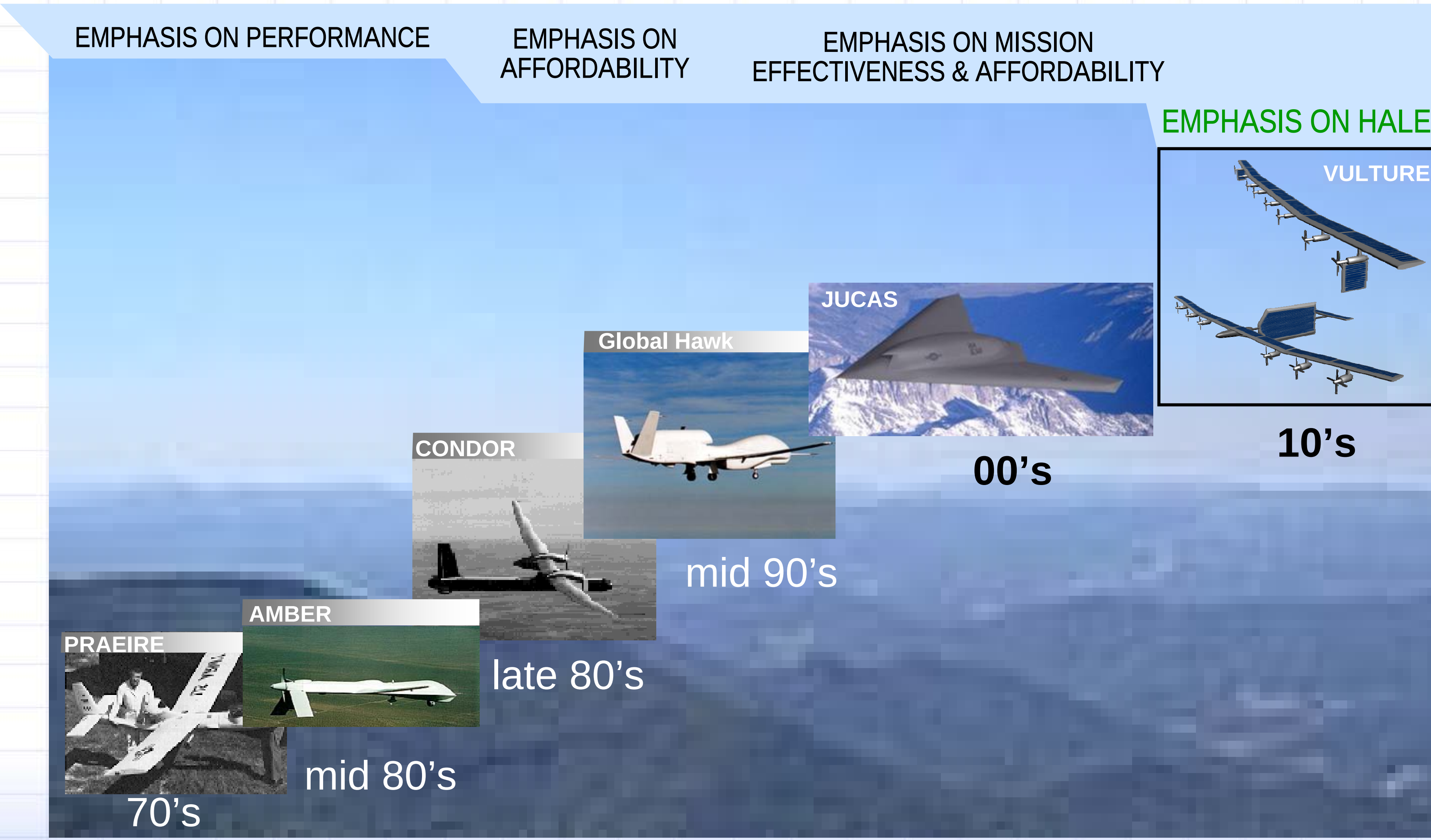
TTO UAV Air Legacy



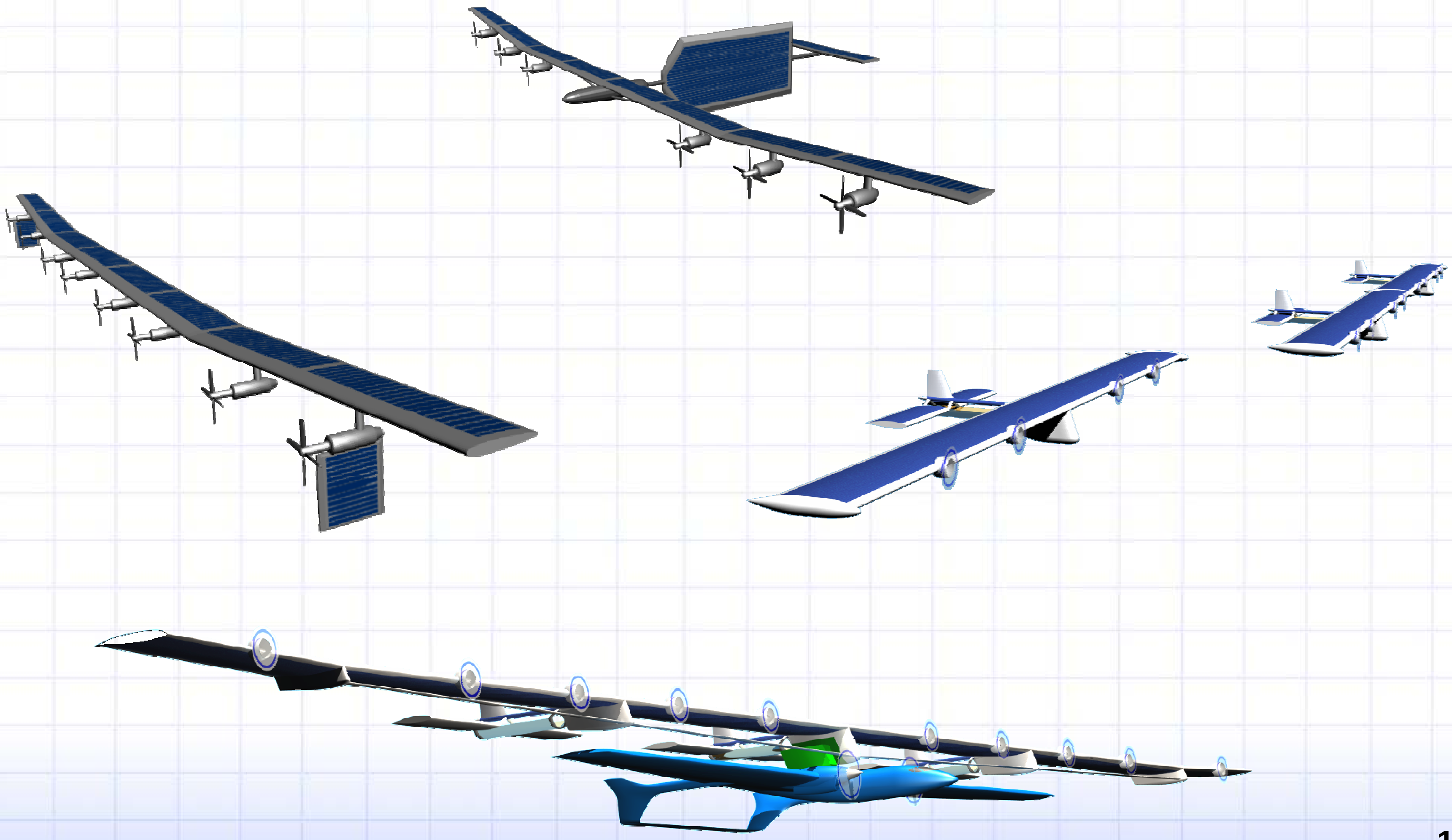
Global Hawk #3 Returns


EDWARDS AIR FORCE BASE, CA -- After supporting the Global War on Terror for three years, Global Hawk unmanned aerial vehicle number three received its official homecoming today when its wheels touched down at 11:30 am Pacific Time (23 Feb 06) at Edwards Air Force Base, CA (US Air Force photos by Chad Bellay)

Record -- Single greatest combat flight hours for any USAF aircraft

- **More than 4800 flight hours over three years**
- **Deployed as advanced concept technology demonstrator**
- **Supported Operation Iraqi Freedom, Operation Enduring Freedom and Combined Task Force – Horn of Africa**

VULTURE: Five Year Endurance



Program Overview

Dr. Wade Pulliam
DARPA / TTO

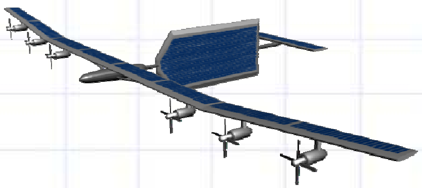
Change the Way We Think About Aircraft

Operate like a satellite

5 years at a time

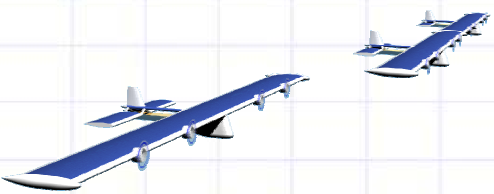
Break the mindset that aircraft are defined by launch, recovery, and maintenance cycles

200X Voyager Endurance Record



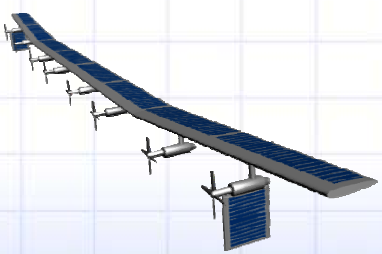
Pseudo-Satellite benefits

- Increased platform availability
- Consistent and persistent coverage
- Smaller fleet size



Possible Payloads

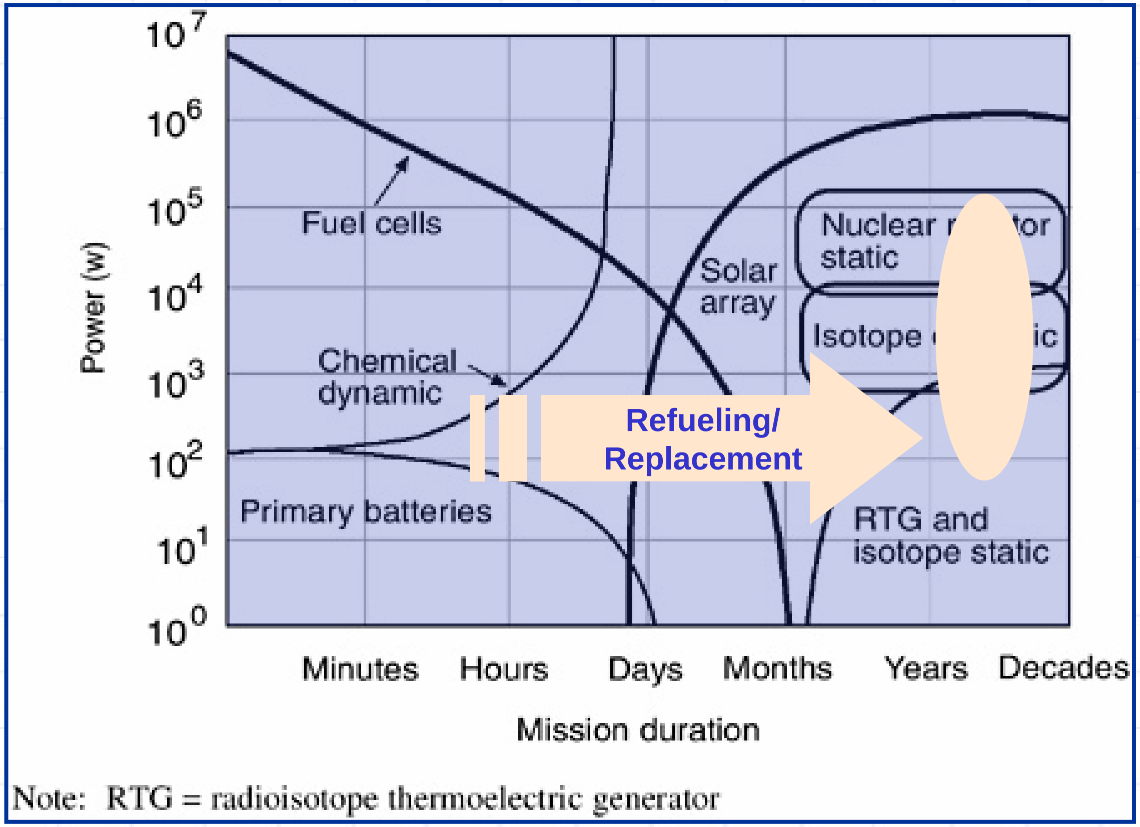
- Communications relay
- ISR
- SIGINT
- Perhaps Strike



Fundamental Issues

- Energy Cycle – Collection or refueling
- Reliability - Ultra-reliable or repairable system

Power Technology Options



Source:
Uninhabited Air Vehicles: Enabling Science for Military Systems
National Materials Advisory Board (NMAB)
Aeronautics and Space Engineering Board (ASEB)

Multi-year flight limits the options for powering the aircraft

Refueling/Replacement

- **Allows more capable aircraft**
- **Requires significant system cost and complexity**

Environmental Harvesting

- **One aircraft solution**
- **Lowest power option**

Nuclear Solutions will NOT be Considered

Reliability is the Key

VULTURE reliability goal is > 200X that of any other aircraft

Global Observer goal is 7 days

VULTURE's goal is 5 years

Design for inherent reliability by building as a satellite

Designed for inherent reliability

- Use highly reliable components to achieve function of low reliability components
  - For example, differential propulsion for control
- Reduce the need for low reliability parts
  - Inherent stability reduces cycles on control systems
- Minimize stresses on components
- Reduce the number of components that impact failure

Use of satellite based system architectures

- Push reliability of all components
- Have redundant systems for those likely to fail
- Degrade gracefully instead of catastrophically
- Reduce part count, especially of moving parts
- Use derated components to increase lifetime

VULTURE Program Requirements

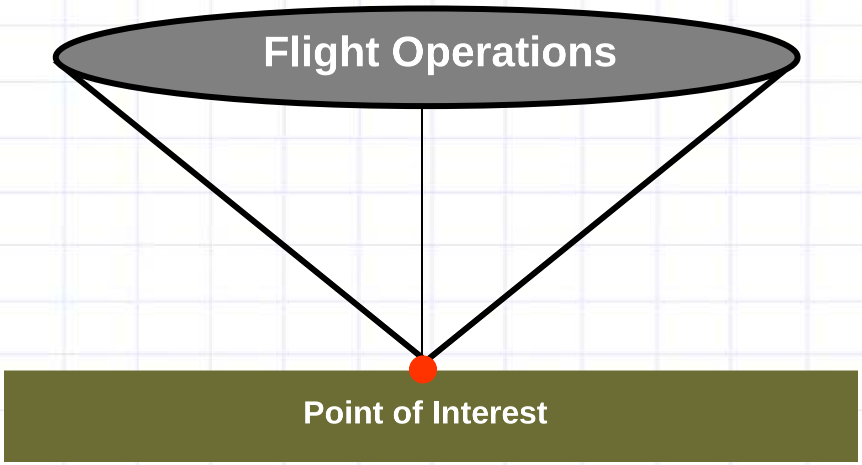
Requirement 1 - Payload

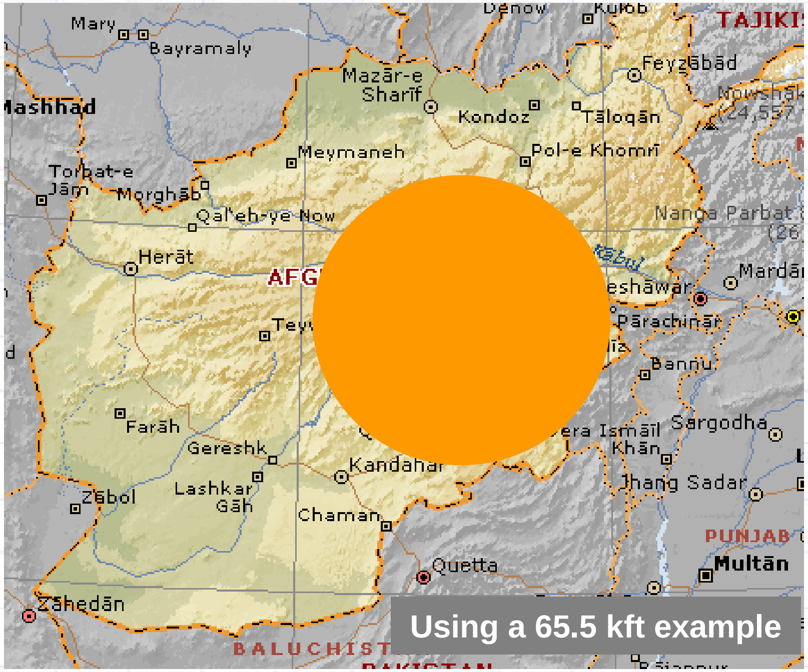
- 1000 lbs
- 5kW

Requirement 2 - Reliability

- 5 year endurance aircraft using a single payload
- Design loiter speed to allow 99+% time-on-station

Persistence Over Target

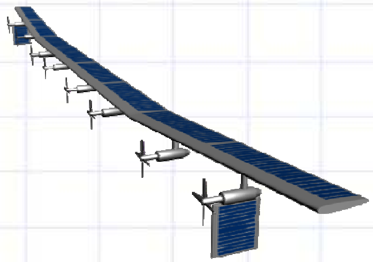


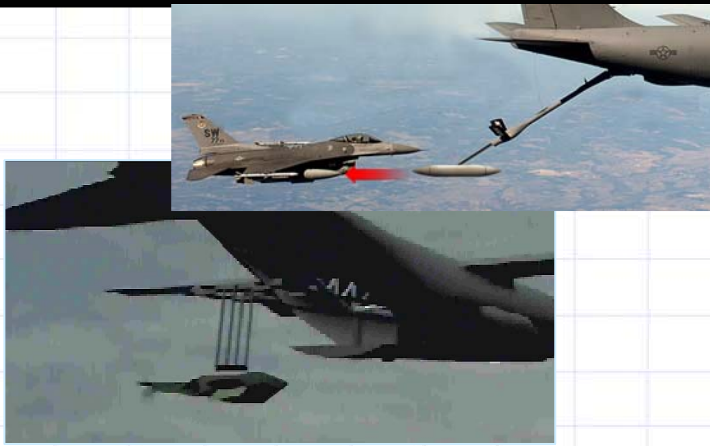


Persistence is not sufficient – Must be persistent over a target area

- Although mission/payload is not defined, clearly EO/IR and comms are possibilities
- System must remain within useful distance to the point of interest 99+% of the 5 years
- Need to consider
  - **Winds**
  - **Turning radius**
  - **Etc.**

"Spacecraft-like" Architecture Options





"Single System" reliability

Use lessons from the satellite community combined with subsystem redundancy to drive the single aircraft reliability up

Conventional Satellite

"Fly Home" reliability

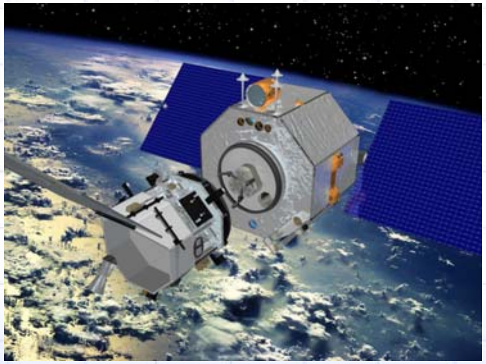
The aircraft system incorporates modular pieces which can fly home when a fault is detected to be replaced

F 6 concept

"In-Flight Servicing" reliability

The aircraft joins with another which replaces/repairs failing systems in or near its operational location

Orbital Express concept



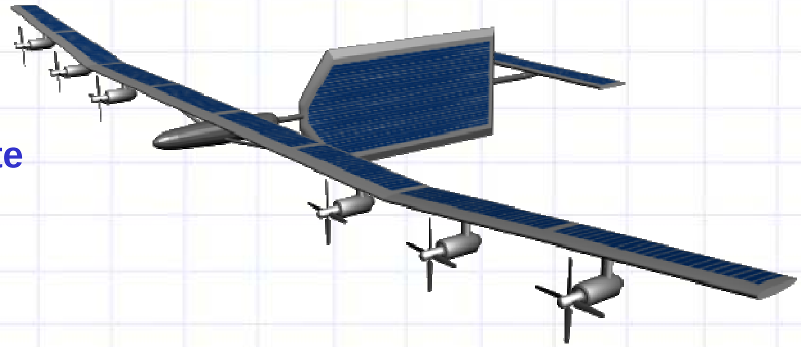
The trades for the best solution will depend on mission and payload

Single Aircraft Option

Use lessons from the satellite community combined with subsystem redundancy to increase single aircraft reliability

Energy cycle

Must be energy harvesting – such as solar



Reliability

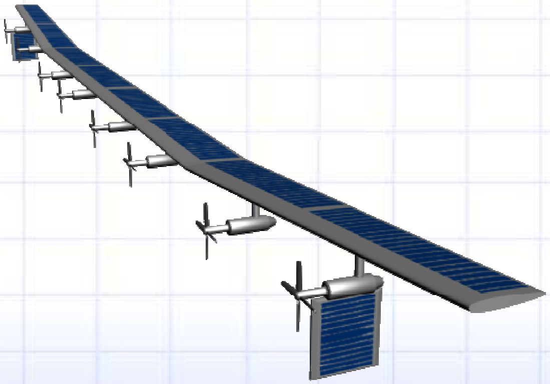
Must develop highly reliable components, incorporate redundancy or design around the need to low MTBF components

Advantages

Minimal fleet size and operational costs

Minimizes take-offs/landings/rendezvous that increase likelihood of aircraft loss

Simplifies ConOps



Problems to be Solved

Energy for year-around flight – limits latitude and therefore world coverage

solar cells, fuel cell, structural advances

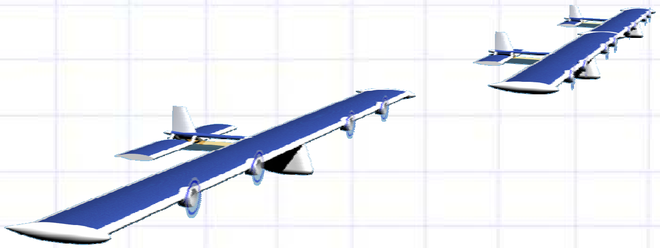
MTBE of propulsion, sensors, avionics, and flight control hardware

"Fly Home" Option

The system incorporates modular pieces which fly home when a fault is detected to be replaced. The pieces fly more efficiently as a group

Energy cycle

- Modular aircraft could bring fuel
- Each piece could be solar/electric, decreasing frequency of replacement and reduced capability



Reliability

- Solves reliability issues of the propulsion system and airframe
- Payload reliability next roadblock (not part of program)

Advantages

- Solves the energy cycle problem
- Not tied to sun output – worldwide coverage
- Simplifies the reliability issue

Tom-Tom Experiment

Problems to be Solved

- Structurally linking in flight without greatly increasing odds of loss of the aircraft
- Linking designs that do not have a significant weight or aerodynamic penalty
- Improved flight control
- Improved MTBF of sensor systems

Refueling/Replacement Option

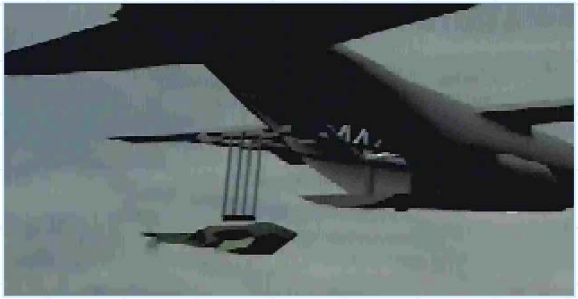
The aircraft joins with another system which replaces/repairs failing systems in or near its operational location

Energy cycle

The repairing vehicle would also refuel the aircraft

Reliability

Solves reliability to the propulsion system and airframe



Advantages

Not tied to sun output – worldwide coverage

Solves both energy cycle and reliability issues

Allows structurally and aero efficient primary aircraft solution

Similar to current ConOps

Problems to be Solved

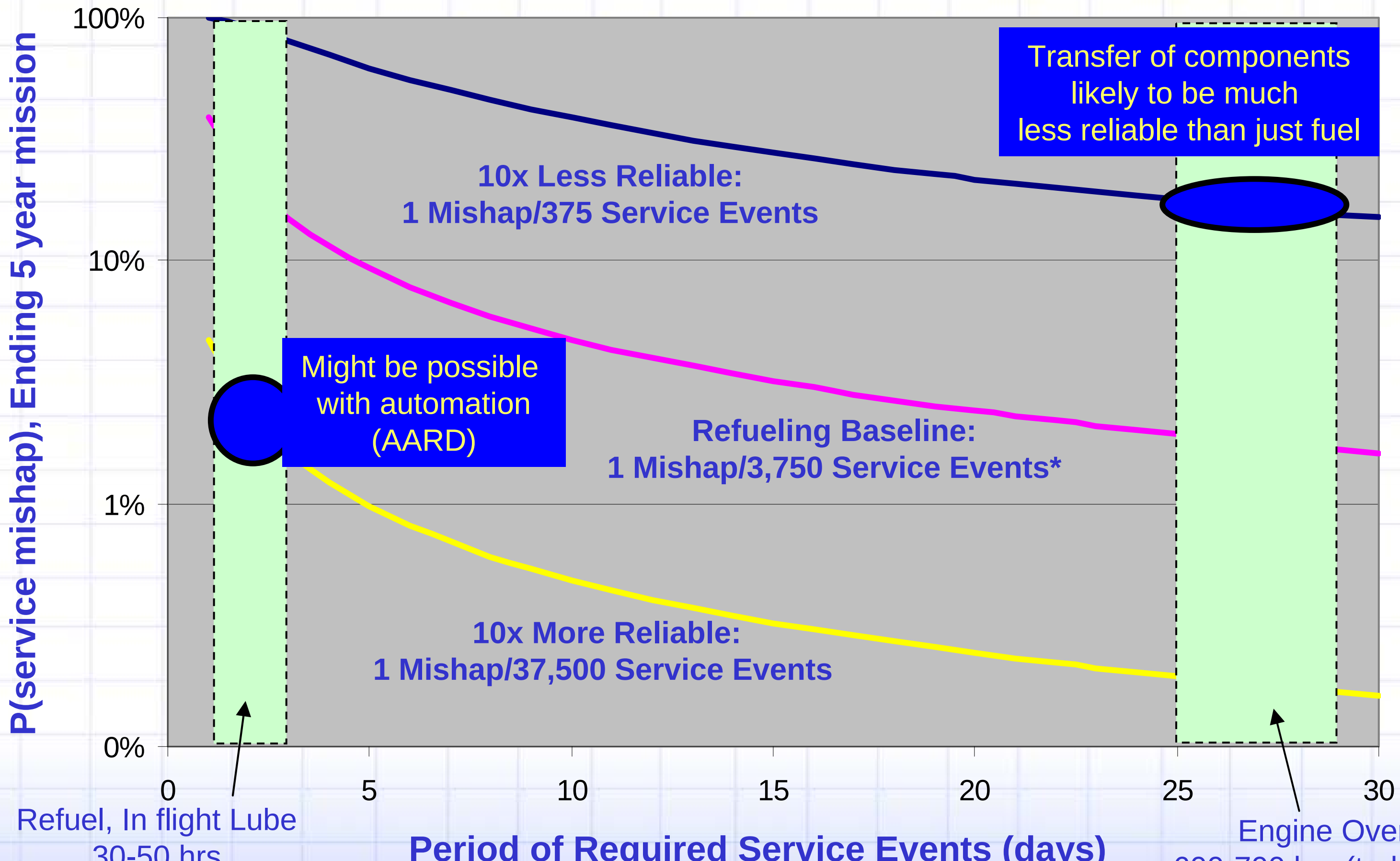
Structurally linking in flight without greatly increasing odds of loss of the aircraft

Design principles to allow replacement of failing or failed components

Capability to swap core components on a flying aircraft

Fly-Home and In-Flight Options Require Low Probability of Mishap

- Mid-air refueling is difficult: Air-Air Service must be infrequent, very reliable
- Components swapping or hard docking will likely be much less reliable
- Increasing endurance and reliability lowers risk



*F-18 aerial refueling data from Air Force tankers in 2003-2004

Servicing Challenges
(Based on Turbine-based UAV)

Endurance limiting factors	Time between events (hours)	# Events per 44,000 hr mission	Strategies to Extend
Fuel	~30	1467	Air-refuel, or Fly-home
Engine Lubrication	~50	880	Fly-home, or In-flight engine lube
Engine Overhaul	~600	73	Fly-home, or In-flight engine switch
Airframe Life	~10,000	4	Fly-home

~ 2500 Total Events

Fly-Home architecture must greatly improve reliability of mating
In-Flight architecture must demonstrate component swapping

Technology Challenges
- Reliability design
- Oil, lube, service in flight
- Aircraft docking
- In-flight engine switch

Risks
- Mission gap: failed fuel, service missions
- Aircraft damage or loss: fueling, docking

Servicing Challenges

(Solid Oxide Fuel Cell: JP-8 or H2, Refueled)

Endurance limiting factors	Time between (hours)	# Events per 44,000 hr mission	Strategies to Extend
Fuel	~168 - 720	~262 – 60	• Air-refuel, or Fly-home
A/C Moving Parts (Actuators, valves, etc.)	~5000	8	• Fly-home, or In-flight repair • Design for ultra-reliability • Leverage emerging electromechanical actuators
Electric Motor Life	~30,000	1.5	• Extend to 45,000 (permanent magnet) or 75,000+ hrs (magnetic bearings)
Solid Oxide Fuel Cell	~20,000 – 65,000	~2.2 - 0	• Fly-home, or In-flight engine switch • Extend static plant performance to airborne (Key: materials, valves)

~ 278 Total Events - ~ 10% of equivalent turbine UAV

Vast improvement in reliability

Technology Challenges
- In-flight refuel, and possible repair
- Extend life of motors, SOFC, actuators

Risks
- Lower than A/C requiring more frequent service

Servicing Challenges

(Solar Powered, Regenerative Solid Oxide Fuel Cell)

Endurance limiting factors	Time between (hours)	# Events per 44,000 hr mission	Strategies to Extend
Fuel	N/A	N/A	• Regenerative SOFC store overnight power
A/C Moving Parts (Actuators, valves, etc.)	~5000	8	• Fly-home, or In-flight repair • Design for ultra-reliability • Leverage emerging electromechanical actuators
Electric Motor Life	~30,000	1.5	• Extend to 45,000 (permanent magnet) or 75,000+ hrs (magnetic bearings)
Solid Oxide Fuel Cell	~20,000 – 65,000	~2.2 - 0	• Fly-home, or In-flight engine switch • Extend static plant performance to airborne (Key: materials, valves)

~ 11 Total Events

Possible path to very reliable system

Technology Challenges

- Same as SOFC/refuel, but without refuel service risk

Risks

- Same as SOFC

Implications for Manufacturing of a 5-Year Aircraft

New regime for reliability engineering

- Design for reliability, learning curves not allowed
- May require more than “space-like” design and manufacturing practice
- Prognostics and state driven maintenance may be problematic because of time and numbers

Testing and milestone verification are difficult

- Is accelerated aging valid?

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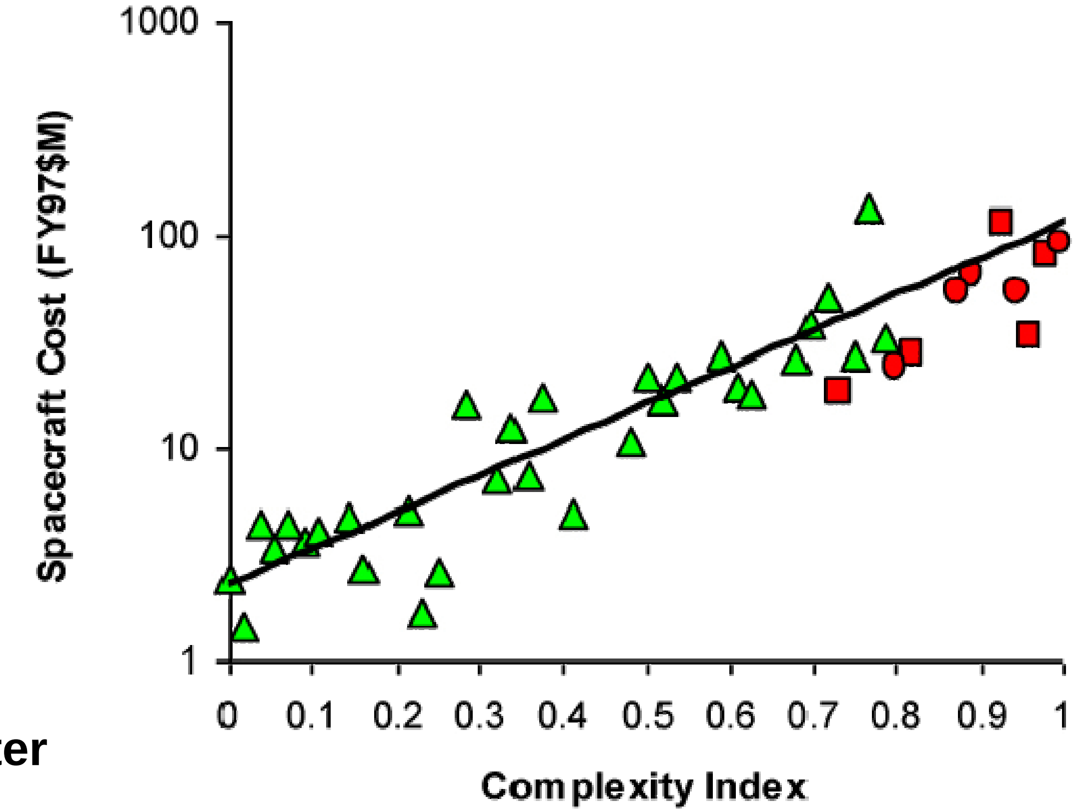
High Reliability Systems:

Lessons from the Space Program

Jim Van Laak
NASA Langley Research Center
June 7, 2007

High Reliability Systems

Lessons from the Space Program

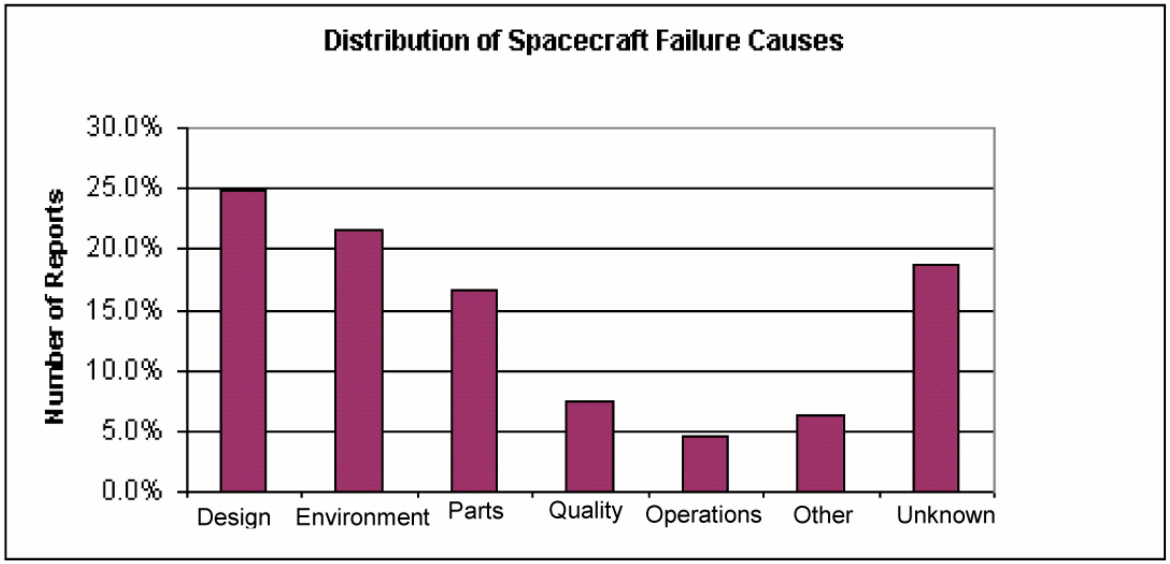


Jim Van Laak
NASA Langley Research Center

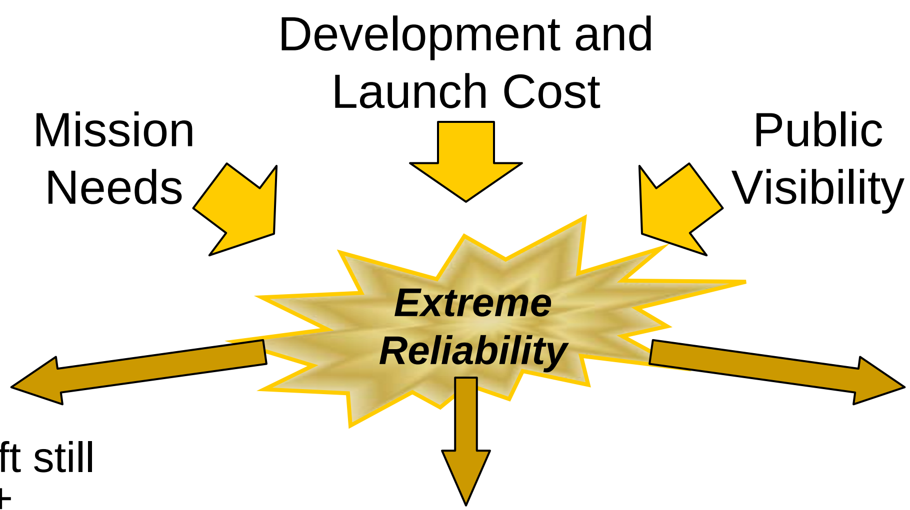
June 7, 2007

Contents

- Introduction
- Mission Success
- Ops scenario and architecture



Introduction



Simplicity

- Voyager spacecraft still operating after 30+ years
- Mars Rovers exceeded mission duration goals by 1000%

Complex redundancy & sophisticated systems management

- Space Shuttle: Reliability requires extensive work between flights
- Space Station: Large investment in reliability paid off - most hardware extremely reliable

Robustness

- Russian approach
- Ability to tolerate failures, attrition

- ***History of Success good overall***
- Early problems with technology and requirements
- Systems engineering issues
- Design cost/complexity vs. operational complexity/criticality
- Design and architecture provide broad trade space

Mission Success

- Mission Success – the accomplishment of some or all objectives of the mission/project
  - Identify pre-declared criteria for:
    - Full
    - Partial
    - Minimum
  - Allocate functionality for integrated system performance to
    - Hardware
    - Software
    - Operations
- Reliability – the ability of the system and its elements to perform required functions at the required time
  - Long term functionality
  - Function on demand

Mission Success (cont)

Long term functionality

- Managed stress levels to improve lifetime
  - Thermal
  - Structural
  - Electrical
  - Radiation
  - etc.
- Plan for failure and subsequent recovery
- Installed redundancy, cross strapping, sparing
- Sophisticated system management and downmoding
- Design for graceful degradation when possible
- Include maintenance, system reconfiguration, software patching

- **Function on demand**
- Limited time for recovery
- Installed redundant hardware
  - May include automated activation
- Extensive testing at all levels, emphasizing **system** level
- Tight system integrity/configuration

Both require reliability as a primary design requirement
Specific, mandatory design point
Design, test and operations practices optimized for it

Operations Scenarios and Architecture

- ***Understand*** the mission
- Performance requirements/goals
- Utilize hazard analyses and FMEAs
- Model potential failures and decisions
- Simulate system reliability and responses
- ***Support*** the mission
- Resolve ambiguities in design, functions, signatures
- Build responses into s/w, procedures
- Provide insight into actual system performance
- Do not over-rely on built-in test
- Track as-built performance and trends
- Stay informed – GIDEP, fleet histories, etc.

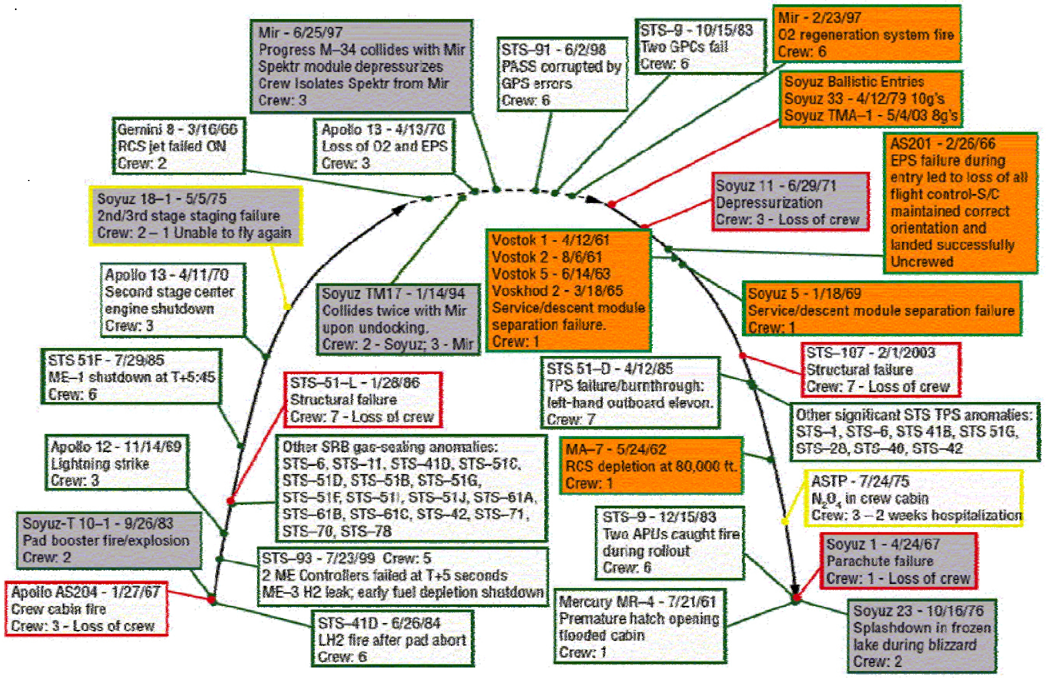
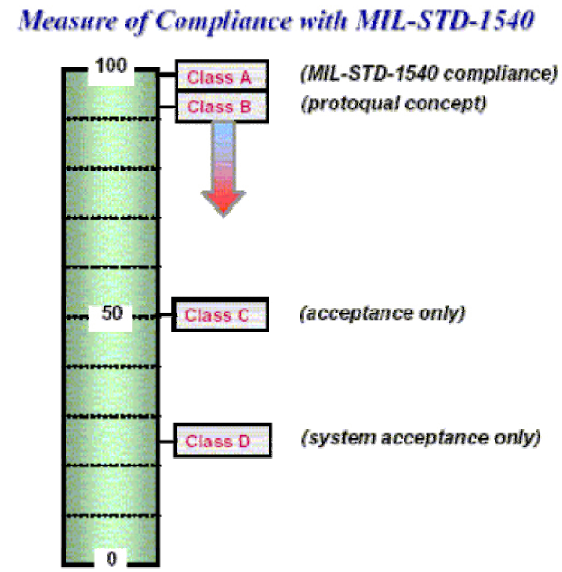


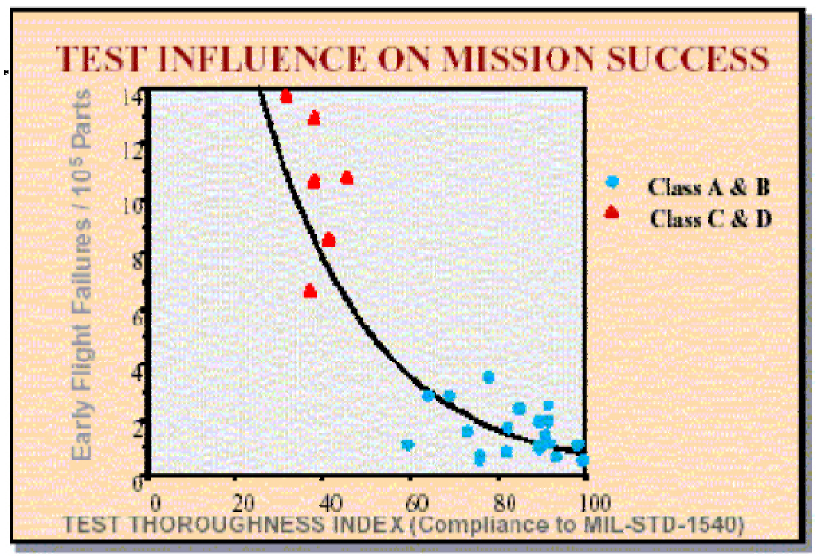
Figure 1.2-1 Significant Human Space Vehicle Failures

Legend: **Red Outline Box = Loss of Crew**
Yellow or Orange = Crew Health Threatened
Green Outline = Significant Event / Close Call, Crew Unaffected

Design Considerations

- Design reliability in
  - Good design practices
  - Selected new technology
- Optimize component reliability
  - Understand performance
    - Environments, stress levels, history, etc.
  - Design/de-rate for margin
    - Low stress = long life, low risk
  - Mechanical parts
    - Detailed analysis of performance, reliability, failure modes
    - Rigorous implementation of MRB process, CM, trending, etc.
    - Thorough testing at component,

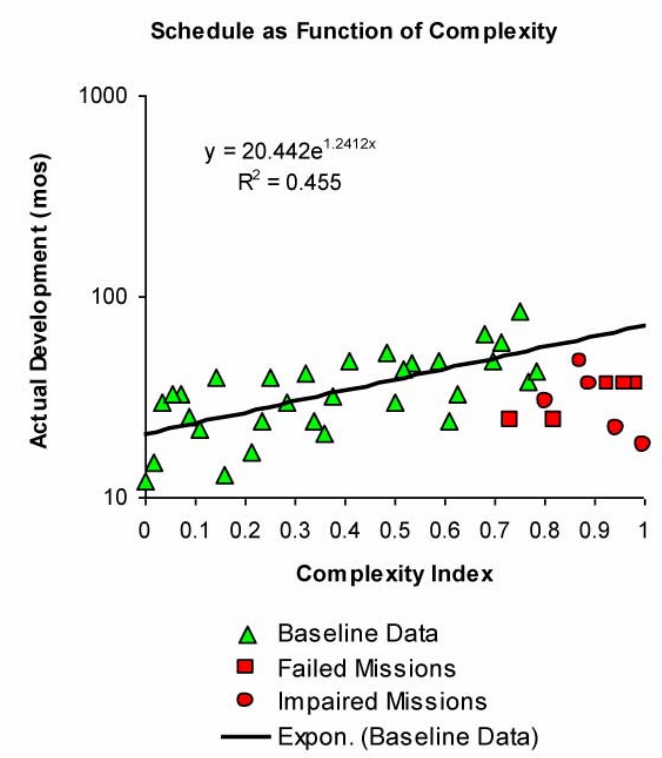


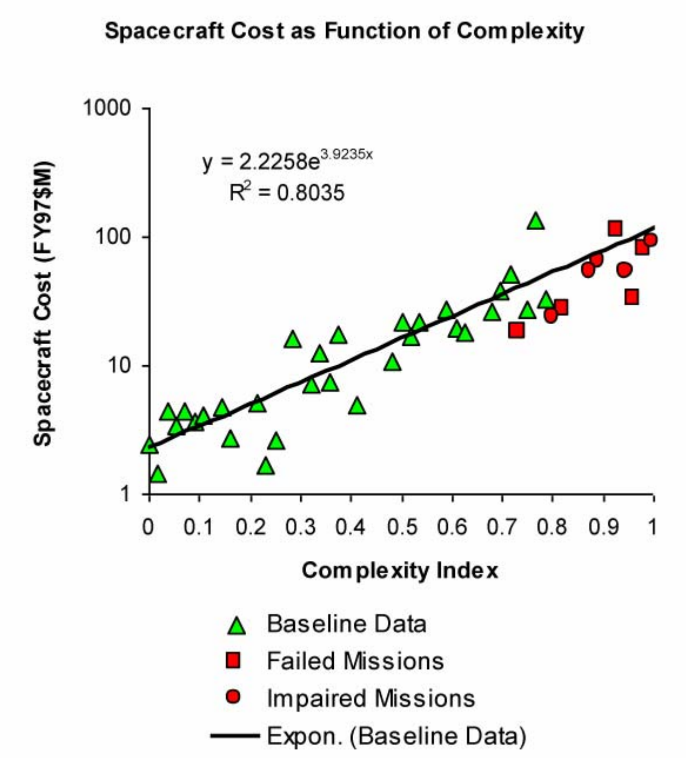


Architectural Robustness

- System robustness
  - Distributed functionality – lose capacity, not function
  - Redundancy – replicate function (may be dissimilar)
  - Margins – reduce stress, protect against dispersions, etc.
- Operational robustness
  - Mission design – tolerate underperformance
  - Adequate assets – tolerate losses and accidents
  - System insight - make informed decisions

Operational Complexity vs. Reliability





Implement only that system complexity required to achieve core system requirements

- Sometimes compete
- KISS principle is intuitive, facilitates design, integration and test
- Complexity can introduce failure modes
- Sometimes allies
- Power of complexity can provide flexibility, insight, robustness

Role of New Technology

- Confidence is built on historical data
- New technology resets the clock on historical data
- Reliability predictions for new technology often unreliable
- Consequences of failures cascade through an integrated system

- Use new technology when *architectural gain offsets component immaturity*.
- Radar design for fighter aircraft
  - Old: corporate transmitter/receiver, waveguides, mechanical gimballing
  - New: solid state transmit/receive modules and phased array scan
  - 2+ orders of magnitude increase in system reliability
- Internal lighting for spacecraft
  - Old: incandescent and florescent
  - New: LED
  - Orders of magnitude reduction in light failure rates, lifetimes
  - Reduced power requirement, heat rejection, lower stress on other systems

Selected Lessons Learned

- Planetary robotic spacecraft
  - Tend to be extremely simple
  - Software size and complexity tigh
- Heritage designs and hardware
  - Reduces risk
    - Limits new/unproven technology to where needed
  - Provides insight and assurance of basic performance
    - Proven design and function
    - Enables incremental expansion of envelope
    - Limit variables in system performance
- Easily misconstrued or misapplied

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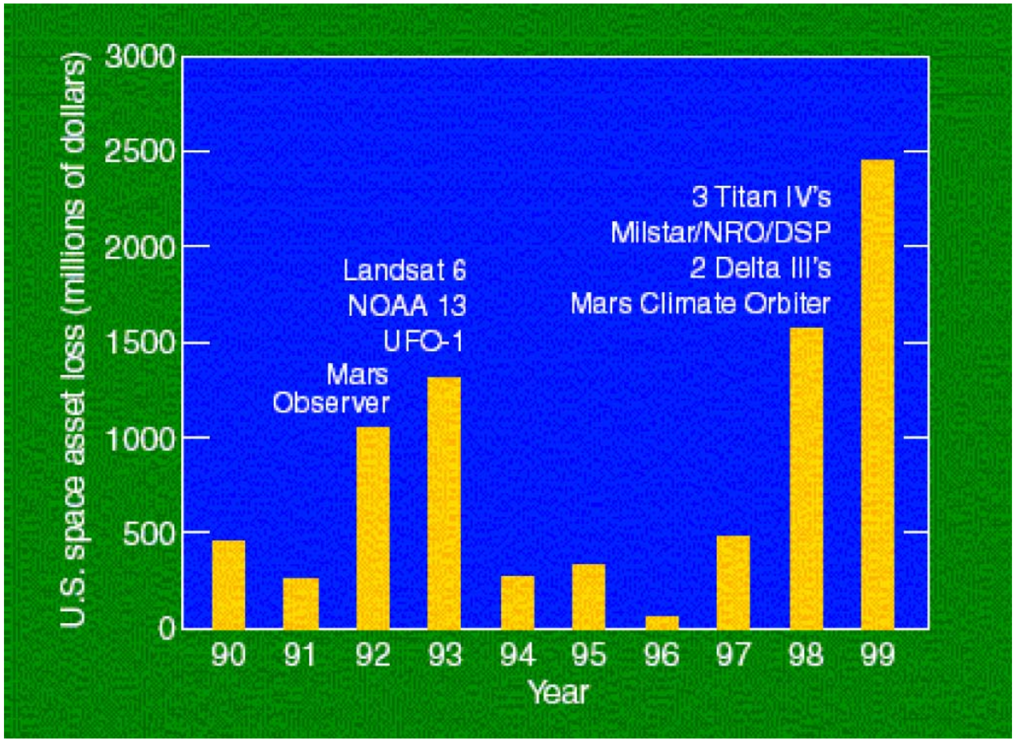
Selected Lessons Learned (cont.)

- Tailor design to ***mission***
- Shuttle incorporated many aircraft practices but…
- Some technology inadequate/inappropriate due to environments, stress level, criticality
- Required high operational involvement to achieve reliability goals
- Trade performance vs. reliability
- High payload mass fractions, high fuel specifics, etc. vs.
- Large margins for structure, thermal, etc.
- Human intelligence vs. automation
- Automate routine functions and monitoring
- Inhibit manual functions where humans reduce reliability
- Enable human intervention where it can improve reliability
- Enable human insight/cognition to resolve ambiguities and make critical decisions

Selected Lessons Learned (cont)

- Test, test, test
  - Inadequate test is a primary finding of failure reports
  - Long lifetimes extremely difficult to test/demonstrate

- Ensure budget and schedule are appropriate for the risk posture
  - Faster, cheaper, disasters



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US vs. Russian Approach

- **US approach:**
  - Stress technology to achieve high performance
  - Build few, complex, high-value assets with high reliability goals
  - Extensive analysis and modeling to reduce testing
  - Test integrated system against planned environments plus margin
    - Note: Very difficult to demonstrate long lifetimes of complex systems

- **Russian approach:**
  - Limited by miniaturization, manufacturing, computational capability
  - Build simple, rugged, robust systems expecting failures
  - Less dependent on analysis
  - Test extensively at every level, including to failure
  - Plan for attrition
  - Plan operations to stay within the capability of the hardware / software

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Conclusions

- VULTURE flight system reliability goals are achievable
  - Other aspects remain challenging
- Require rigorous application of engineering and management best practices:
  - Requirements definition
  - Hardware design, fab, test
- Tied together in an intelligent architecture
  - Apply new technology where it clearly advances reliability
  - Innovate in application of well understood technology
  - Define and execute a robust operations program

Backup

16

NASA Safety and Engineering Center Report

RP-06-108

DDT&E Considerations for Safe and Reliable

Human Rated Spacecraft Systems

http://everest.larc.nasa.gov:8331/V/RPSVI8UBRDECMJJM5A5AMIIQRHY3CI99PRP8V3BA2VM8CM2IAD-08263?func=quick-3&short-format=002&set_number=000433&set_entry=000001&format=999

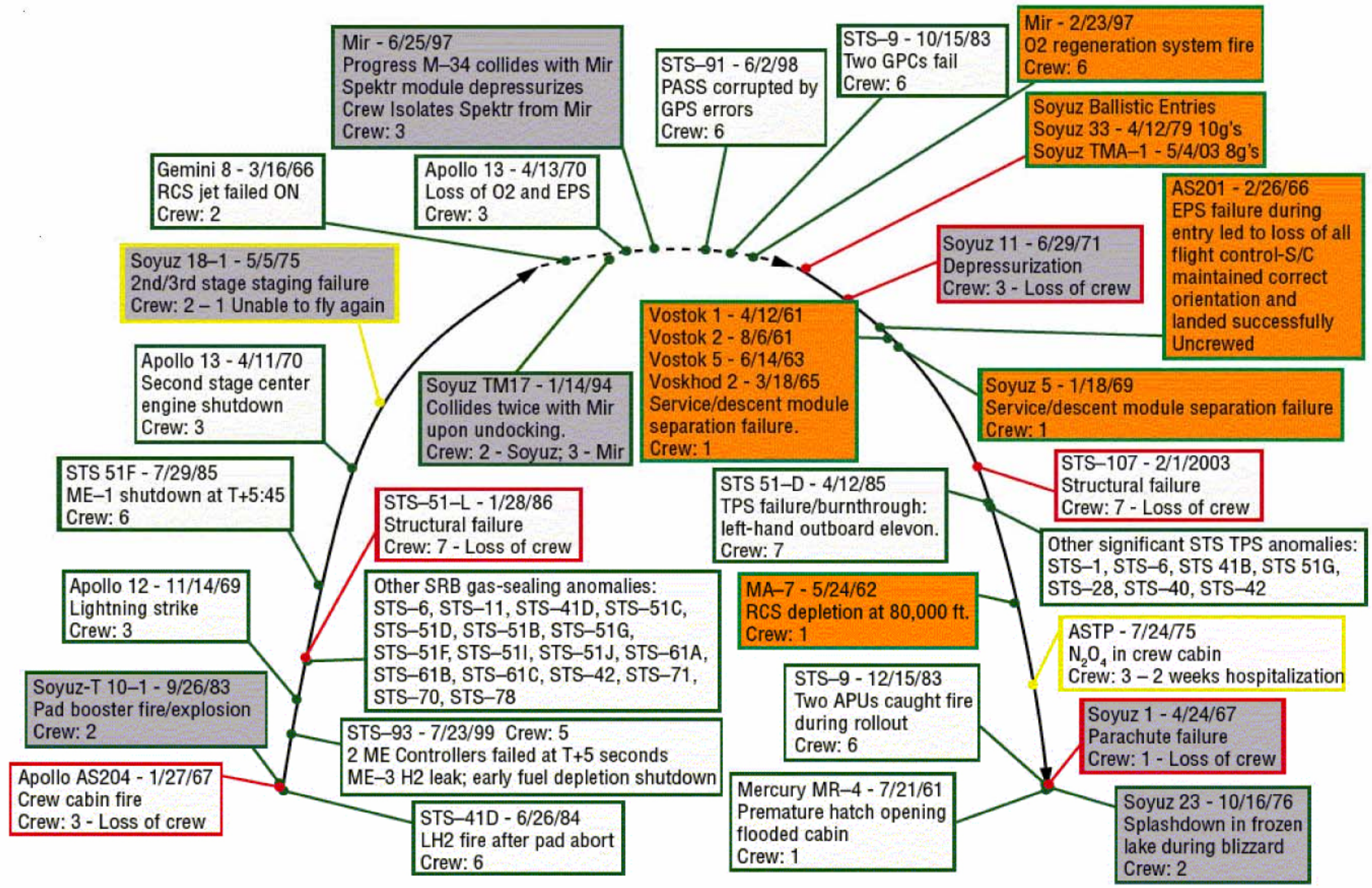

Figure 1.2-1 Significant Human Space Vehicle Failures
Ref: OSP-ELV Human Flight Safety Certification Study Report

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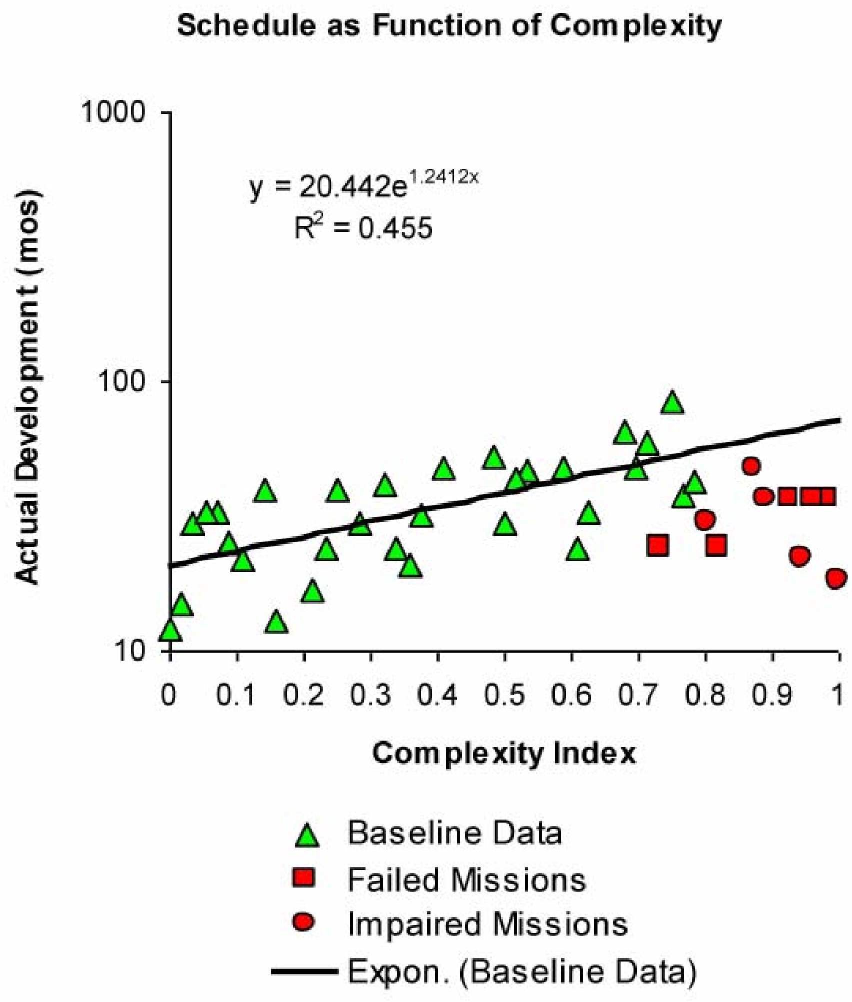
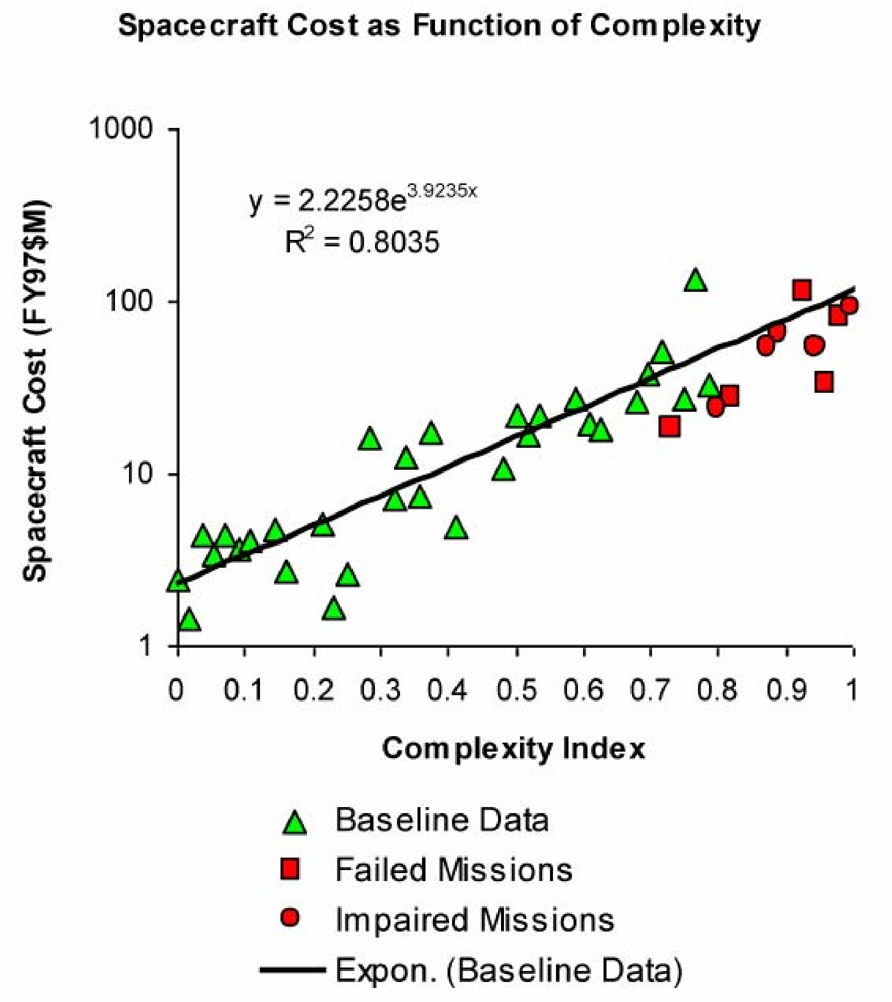
Yellow or Orange = Crew Health Threatened
Green Outline = Significant Event / Close Call, Crew Unaffected

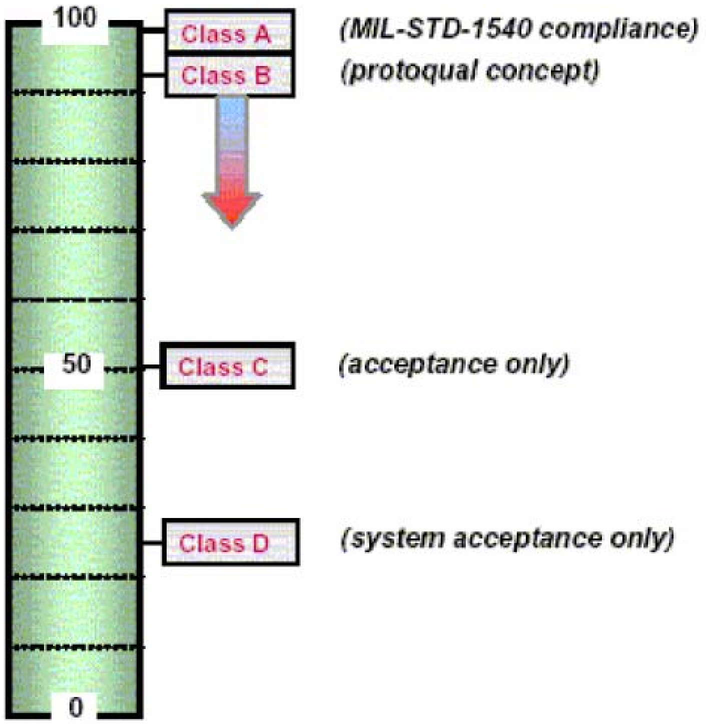


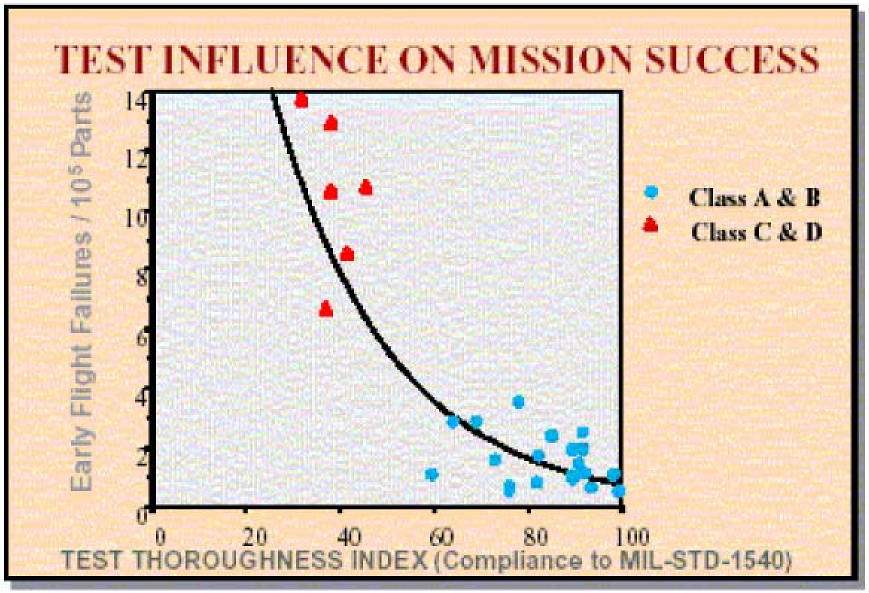
Schedule as Function of Complexity
y = 20.442e^1.2412x
R^2 = 0.455
1000
100
10
Actual Development (mos)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Complexity Index
Baseline Data
Failed Missions
Impaired Missions
Expon. (Baseline Data)



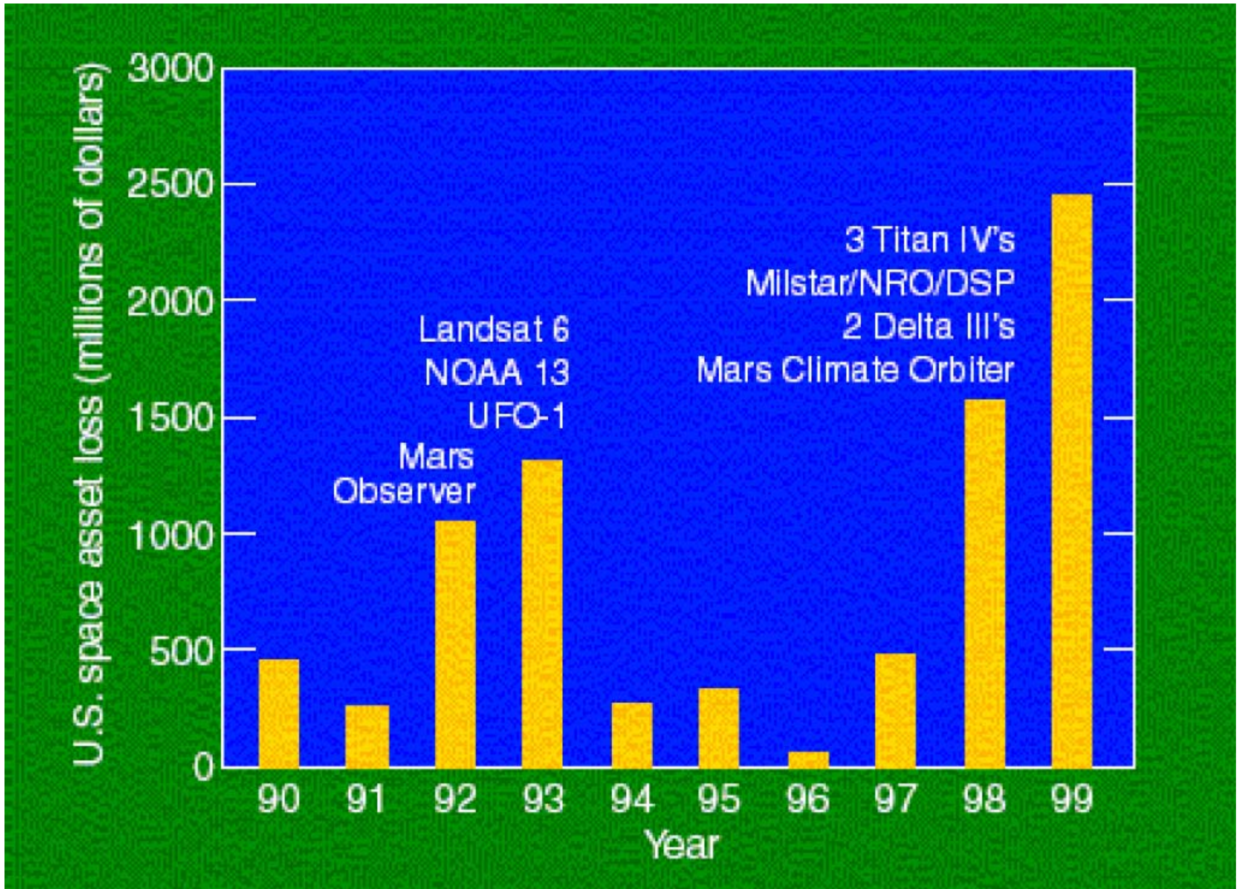
Spacecraft Cost as Function of Complexity
y = 2.2258e^3.9235x
R^2 = 0.8035
1000
100
10
1
Spacecraft Cost (FY97$M)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Complexity Index
Baseline Data
Failed Missions
Impaired Missions
Expon. (Baseline Data)

Measure of Compliance with MIL-STD-1540





- On-orbit mission degrading failure (MDF) rate can be correlated per 100k piece parts
- Computation provides a measure of robustness of the environmental testing program used to approximate risk and highlight areas of concern



This chart shows the value in dollars of U.S. space assets lost during the 1990s. Recent independent studies have shown that reducing technical verification rigor and diminishing the role of independent technical oversight in the development of government and commercial space systems results in greater problems, as evidenced by higher failure rates and cost and schedule overruns.

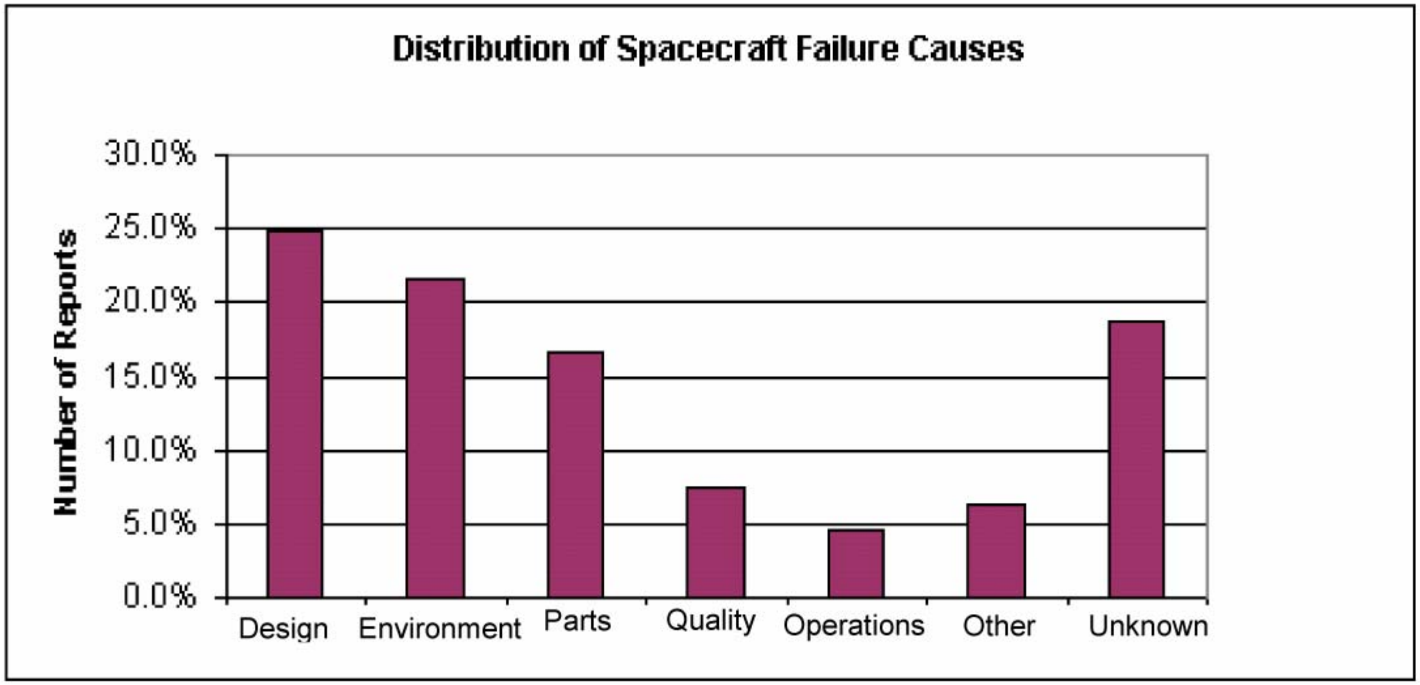


Figure 1.2-8 Reliability Prediction for Spacecraft, RADC-TR-85-229 Rome Air Development Center, H. Hecht & M. Hecht, December 1985

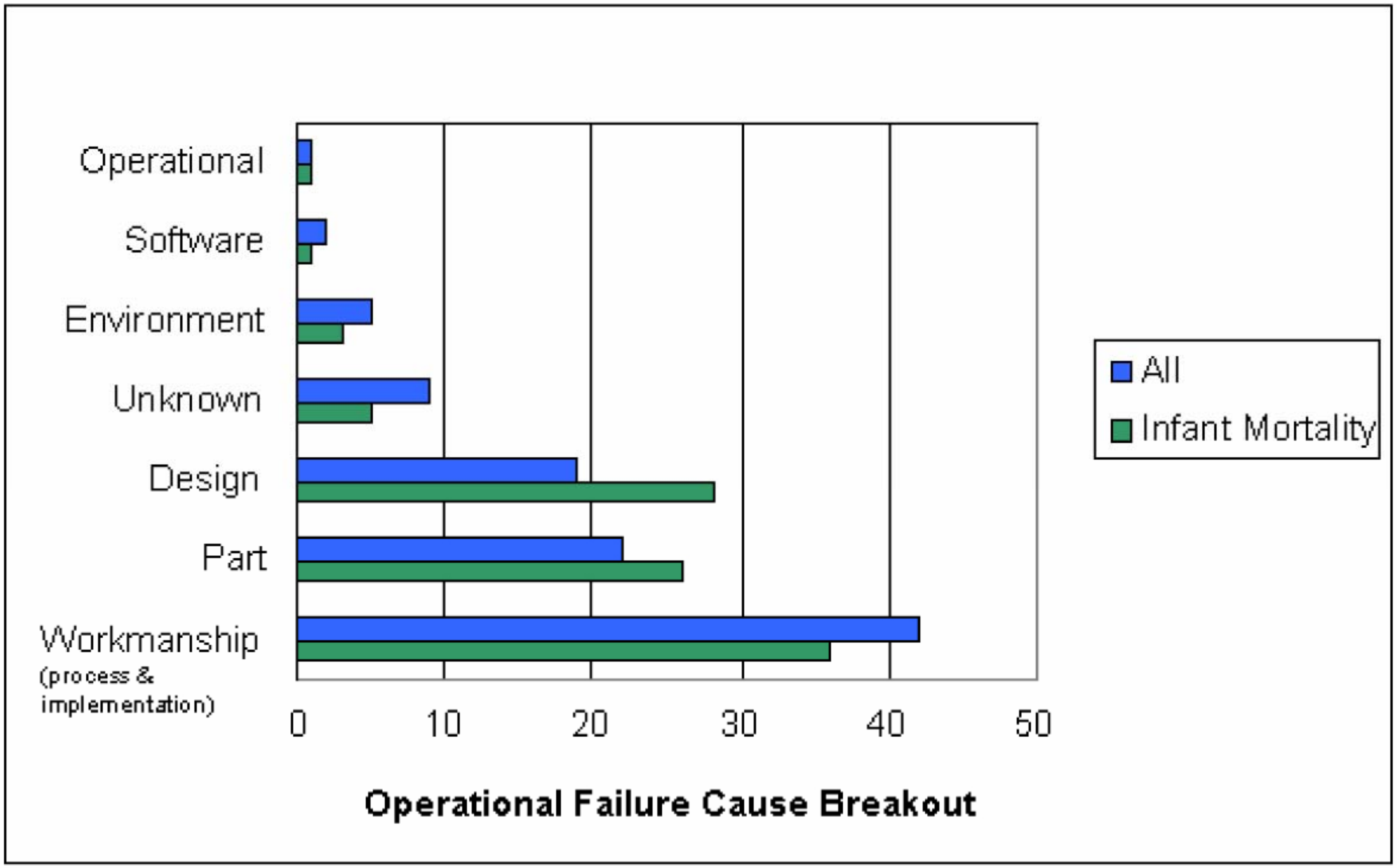


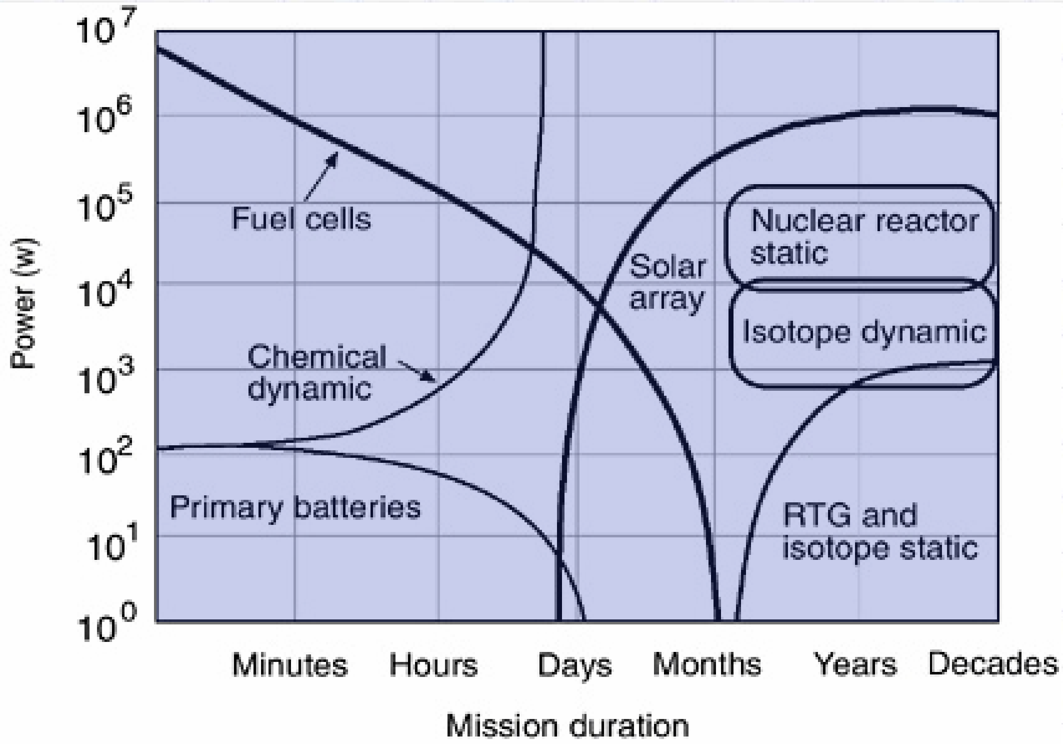
Figure 1.2-7 Orbital Experience from an Integration and Test Perspective
Journal of the IEST, W. F. Tosney & A. H. Quintero, Nov./Dec. 1998

Break

Power Technology Options

Dr. Wade Pulliam
DARPA / TTO

Power Technology Options



Note: RTG = radioisotope thermoelectric generator

Source:
Uninhabited Air Vehicles: Enabling Science for Military Systems
National Materials Advisory Board (NMAB)
Aeronautics and Space Engineering Board (ASEB)

Multi-year flight limits the options for powering the aircraft

Refueling/Replacement

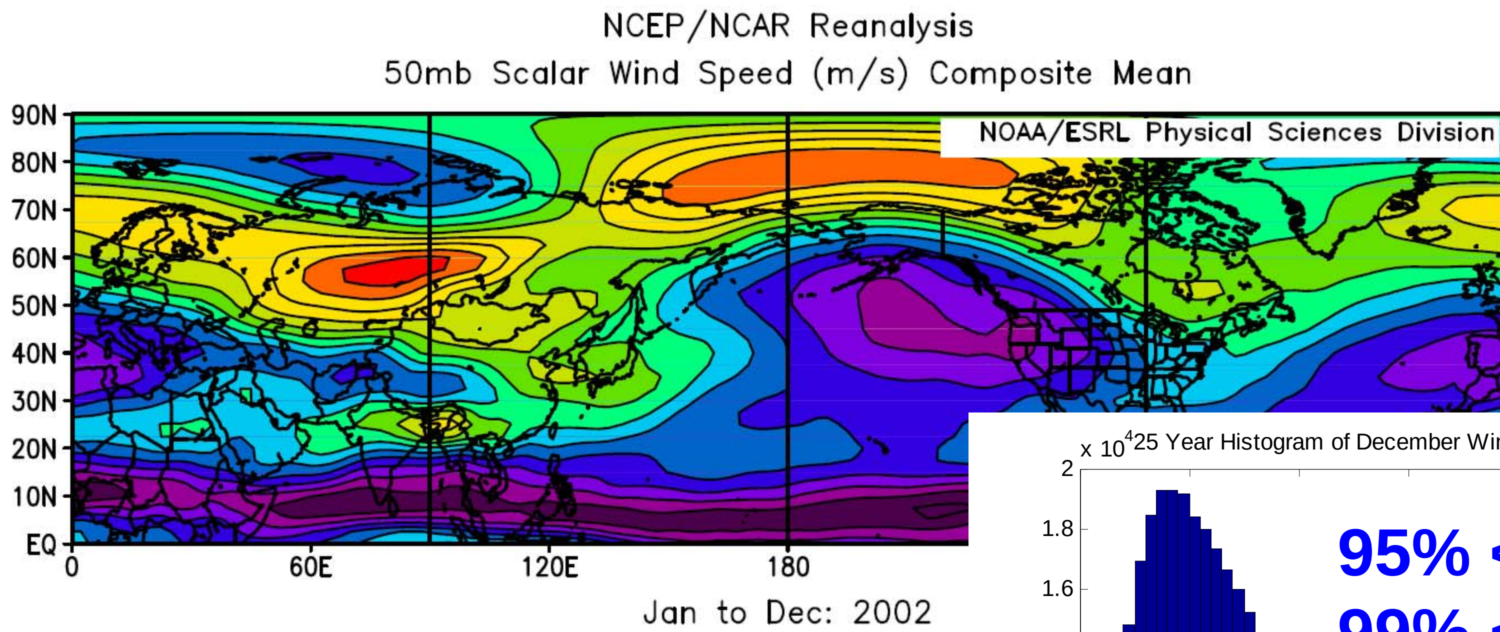
- **Allows more capable aircraft**
- **Requires significant system cost and complexity**

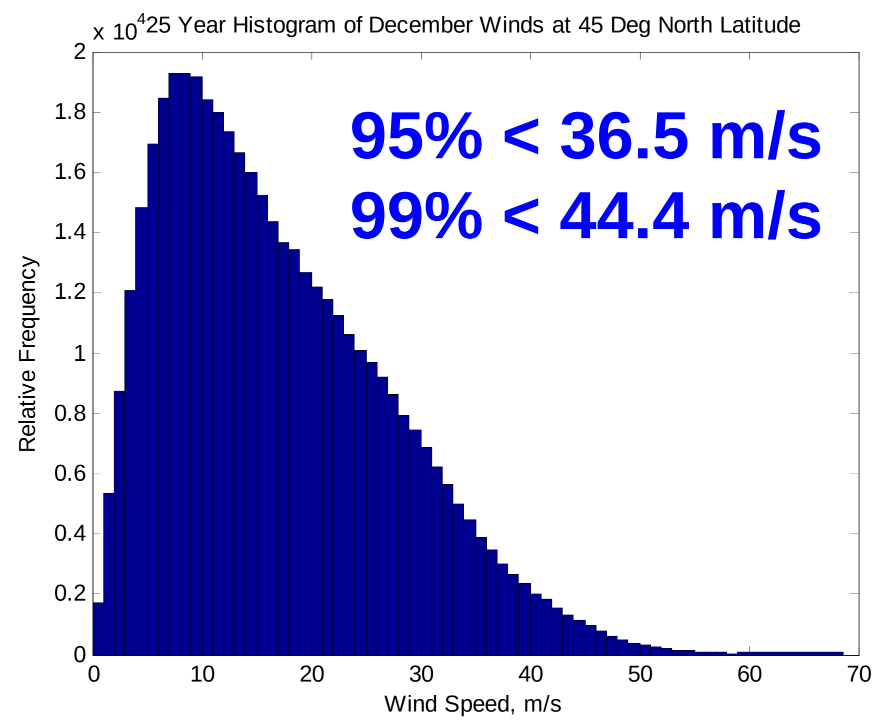
Environmental Harvesting

- **One aircraft solution**
- **Lowest power option**

Nuclear Solutions will NOT be Considered

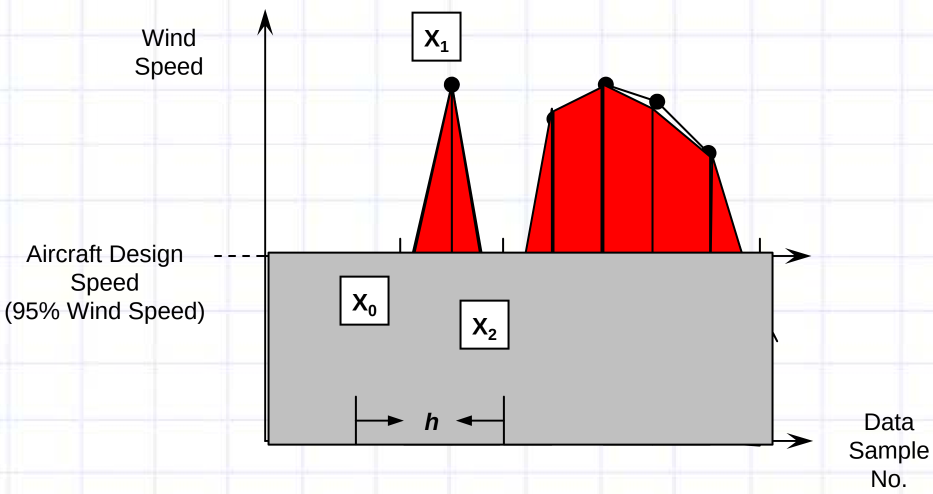
Winds
Higher at High Latitudes in the Winter



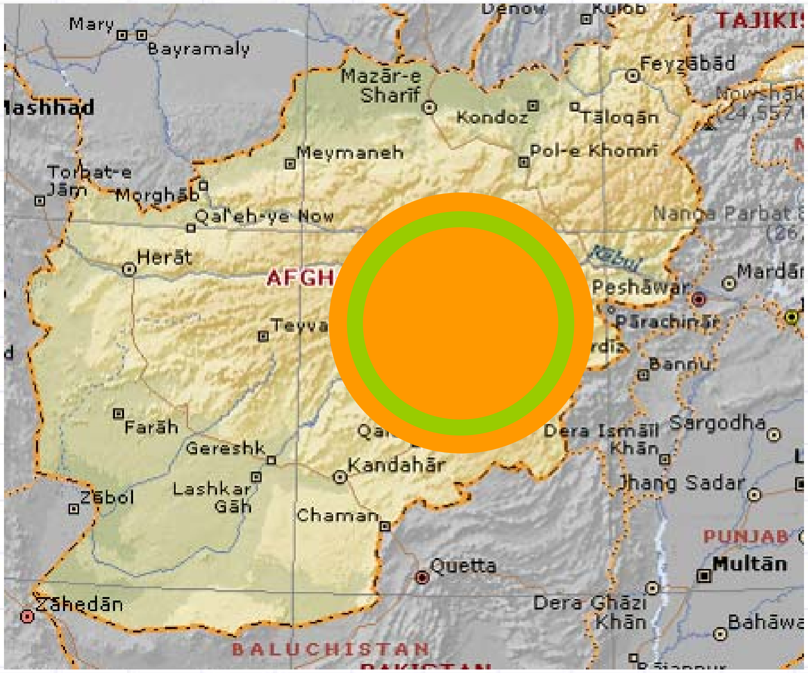


- NCEP winds at measured at 6 hr intervals, worldwide at numerous altitudes
- Typically, loiter requirements are stated in terms of statistical winds, i.e. 2 or 3 sigma

Wind Duration is an Important Issue



$$\int_{x_0}^{x_2} f(x) \approx \frac{1}{3} h\left(f_0 + 4 f_1 + f_2\right)$$



Statistical winds are NOT operationally definitive, must include duration

Allowing a small drift that does not take the sensor system away from the area of interest can greatly reduce power requirements

High Altitude Long Endurance Air Vehicle Analysis of Alternatives and Technology Requirements Development

Craig Nickol
NASA Langley Research Center

High Altitude Long Endurance Air Vehicle Analysis of Alternatives and Technology Requirements Development

VULTURE Program Industry Day Presentation

June 7, 2007

Craig Nickol and Mark Guynn
NASA Langley Research Center

Lisa Kohout
NASA Glenn Research Center

Tom Ozoroski
Swales Aerospace, Inc.

Outline

- Study Objectives and Process
- Mission Requirements
- Analysis of Alternatives (AoA) metrics
- Phase I Heavier-than-air (HTA) Concepts
- Solar Regenerative Mission Requirements Study
- Solar Regenerative Technology Trade Study
- Publication Information

Study Objectives

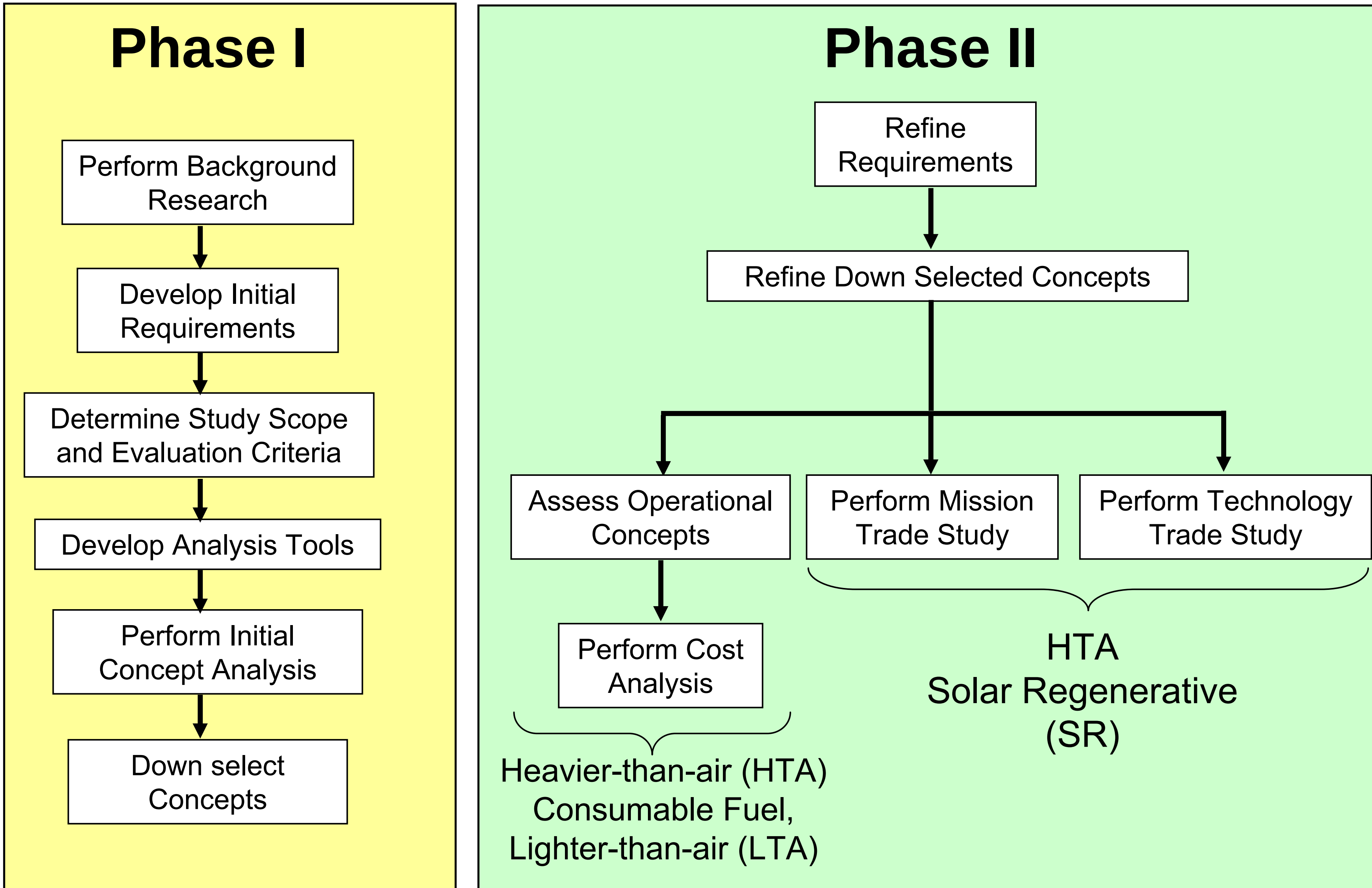
Primary Objectives:

- Benchmark the performance potential of HALE UAV concepts for two long endurance (Goal endurance = 6 months) mission areas:
    - Hurricane Science Mission
    - Communications Relay Mission
- Quantify technology improvements required (if any) to enable these two missions

Status:

- HALE Concept Design Team members from Langley (5), Glenn (2), Ames(1) and Dryden(1) have completed the study and produced an AIAA paper and a NASA Technical Publication (TP).

HALE UAV Study Process

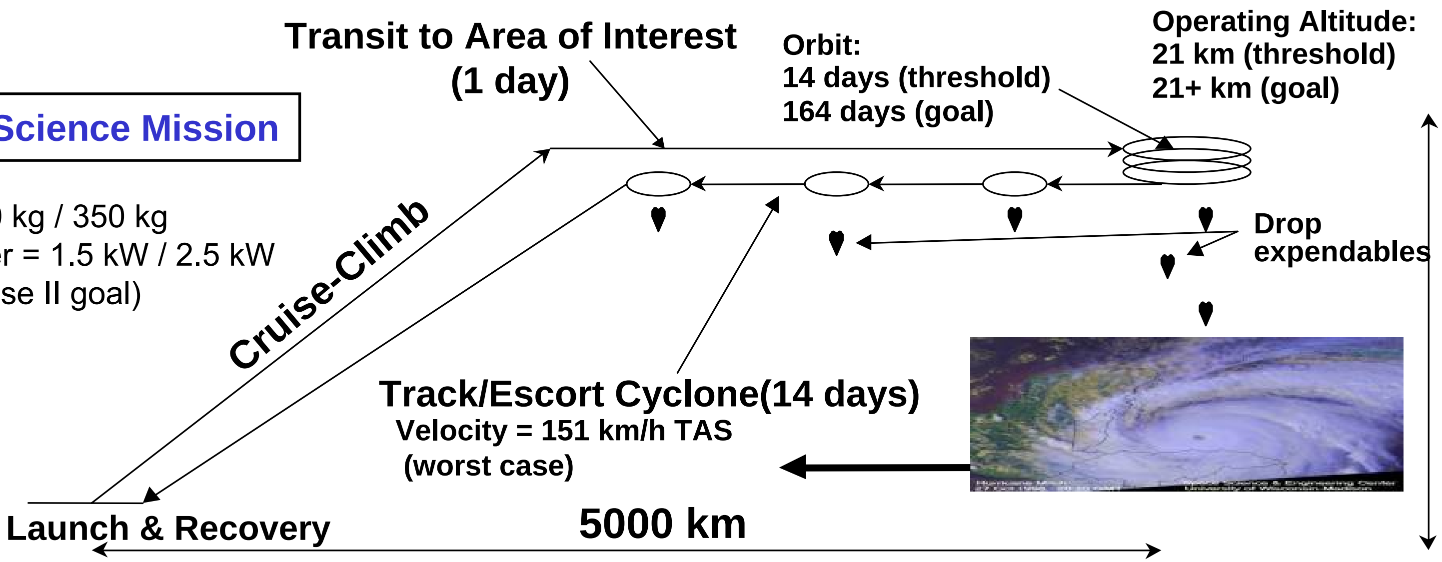


Mission Requirements

Hurricane Science Mission and Communications Relay Mission

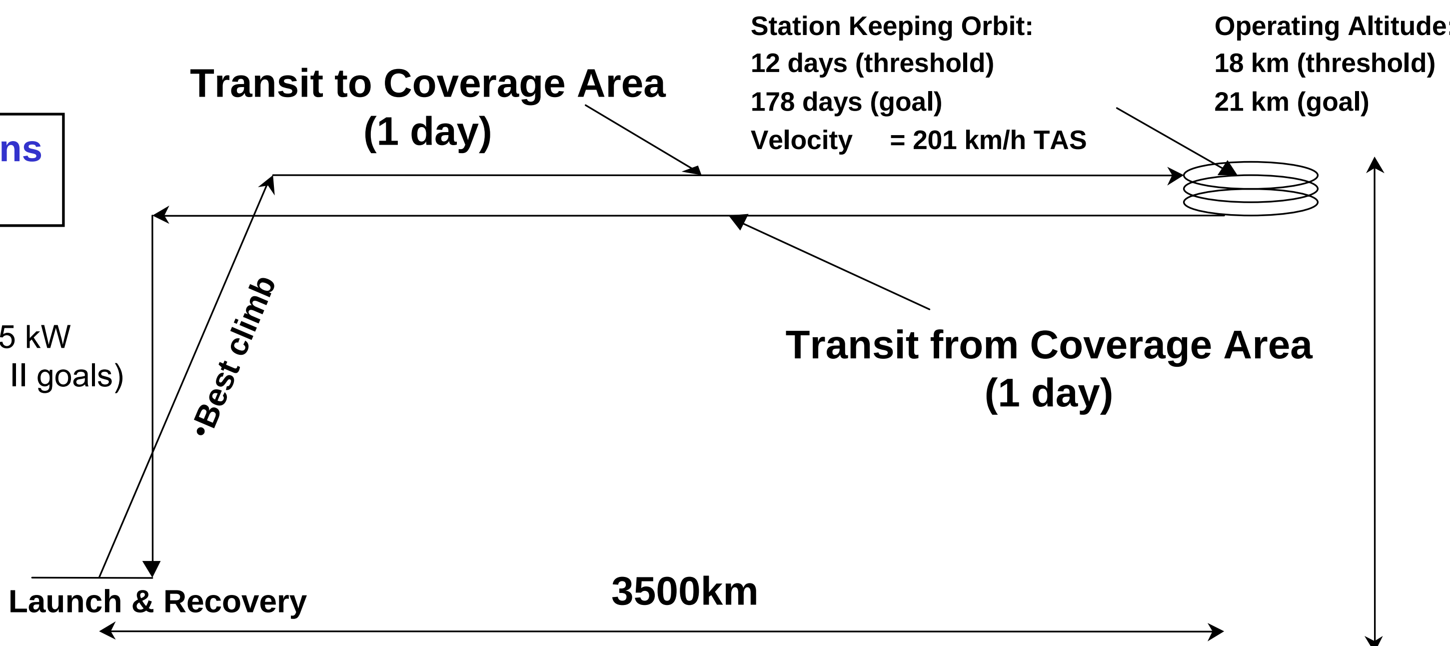
Hurricane Science Mission

Payload = 400 kg / 350 kg
Payload Power = 1.5 kW / 2.5 kW
(Phase I / Phase II goal)



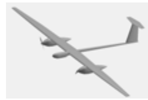
Communications Relay Mission

Payload = 200 kg
Payload Power = 1.5 kW
(Phase I and Phase II goals)

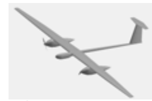


Phase I Concepts

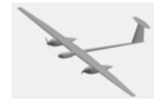
Concepts 1-5
HTA Wing-Body-Tail
Consumable



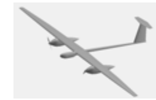
Concept 1
LH_2 IC Engine



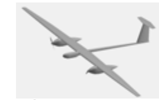
Concept 2
LH_2 Gas Turbine



Concept 3
LH_2 Fuel Cell



Concept 4
LH_2 Stirling



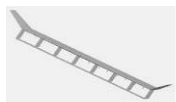
Concept 5
Diesel IC Engine

Concepts 6, 7
HTA All-Wing
Solar Regen

Concept 6
Solar Regen Fuel Cell

Concept 7
Solar Secondary Battery

Concepts 8-10
HTA Planform Alternatives
Solar Regen



Concept 8
Trussed-Wing
Solar 2nd Battery

Concept 9
Joined-Wing
Solar 2nd Battery

Concept 10
Multi-Surface
Solar 2nd Battery

Concepts 11,12
LTA
Consumable

Concept 11
LH_2 IC Engine

Concept 12
LH_2 Primary PEM Fuel Cell

Concepts 13, 14
LTA
Solar Regen

Concept 13
Solar Regen Fuel Cell

Concept 14
Solar Secondary Battery

Concept 15
LTA
Hybrid

Concept 15
LH_2 Primary PEM Fuel Cell + Solar

Concept 16
LTA
Aeroship

Concept 16
10% Dynamic Lift, Solar Regen Fuel Cell

Technology Assumption: TRL 5 by the end of FY08 to support initiation of demonstrator program. TRL 5 is defined as component or breadboard validation in a relevant environment.

AoA Metrics

Metrics		
	TOGM (Hurricane Mission) kg	
	TOGM (Comm. Relay Mission) kg	
	Endurance (days)	Hurricane
		Comm. Relay
	% P_{regen} [1]	Hurricane
		Comm. Relay
	Takeoff and Landing Robustness % [2]	Hurricane
		Comm. Relay
	Ground Footprint [3]	Spot Factor
		Support Required
	Growth Factor [4]	
	Risk [5]	

Structure/Materials
Propulsion system
Subsystems
Vehicle Integration
Test Program

Risk Areas

Fuel Handling
Ground crew size
Propulsion system uniqueness/complexity
Hangaring
Maintenance req'ts
Deployability
Safety

Support Req. Areas

[1]Percentage of the total power required that is supplied by the regen propulsion system on the least favorable day of the mission (100 indicates system closes for a day/night cycle)

[2]Percentage of the mission timeframe that the vehicle can takeoff and land from it's home operating base factoring in cloudiness and average wind speeds.

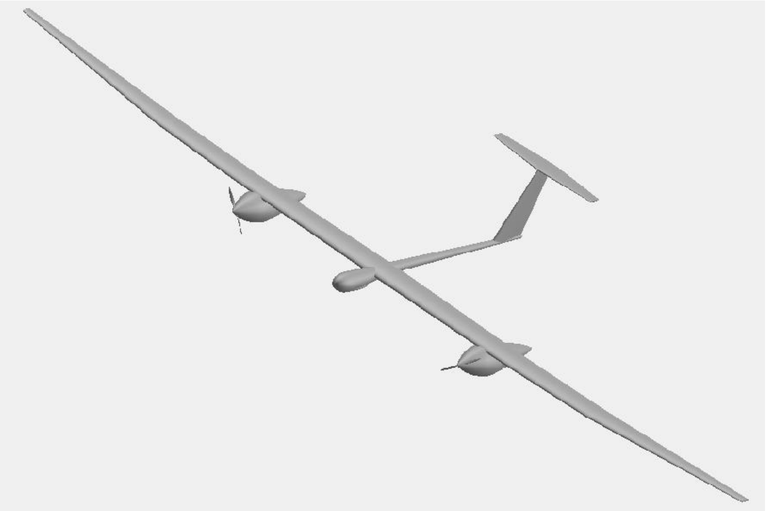
[3]Spot factor is a measure of the vehicle's overall size and ground footprint. Support required is a subjective rating of the amount of ground support equipment and crew required to operate the vehicle.

[4]Growth factor is the number of kilograms the overall configuration grows due to the addition of one extra kilogram of zero fuel weight

[5]Subjective estimate of overall vehicle development and operational risk.

Concept 1

LH_2 Fueled IC Engine Wing-Body-Tail



Wingspan	80 / 262	m / ft
Wing Area	250 / 2690	m^2 / ft^2
Wing AR	25.6	-
Wing Loading	18.5 / 3.77	kg/m^2 / lb/ft^2
Fuel Mass	1440 / 3174	kg / lb
Takeoff Mass	4630 / 10207	kg / lb
Loiter Altitude	18 / 59000	km / ft
Loiter Speed	197 / 122	km/hr / mph
Endurance	10	days (Comm. Relay)

Strengths

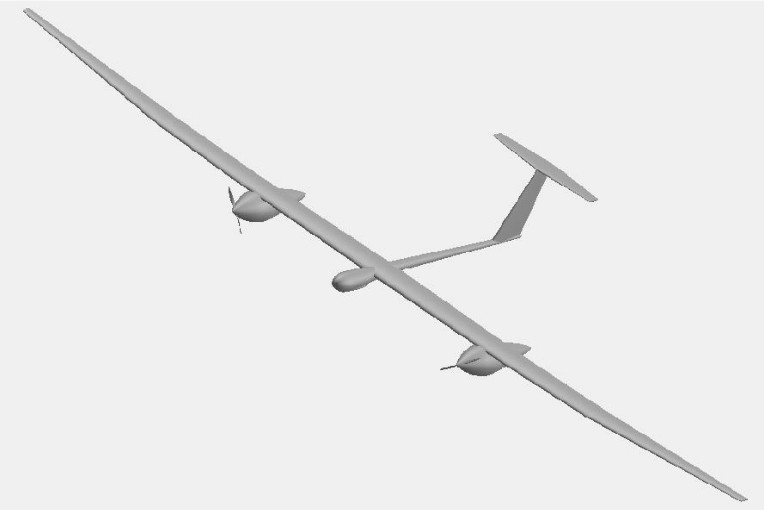
- Greatest endurance of any consumable fueled HTA concept
- High takeoff and landing robustness (i.e. availability) (this applies to all of the wing-body-tail concepts)
- Relatively low risk propulsion system

Weaknesses

- Large spot factor (i.e. ground footprint) complicates handling
- LH_2 fuel impacts engine/fuel system design and ground infrastructure

Concept 2

LH_2 Fueled Gas Turbine Engine Wing-Body-Tail



Wingspan	80 / 262	m / ft
Wing Area	250 / 2690	m^2 / ft^2
Wing AR	25.6	-
Wing Loading	17.9 / 3.6	kg/m^2 / lb/ft^2
Fuel Mass	1490 / 3285	kg / lb
Takeoff Mass	4280 / 9435	kg / lb
Loiter Altitude	18 / 59000	km / ft
Loiter Speed	189 / 117	km/hr / mph
Endurance	9.1	days (Comm. Relay)

Strengths

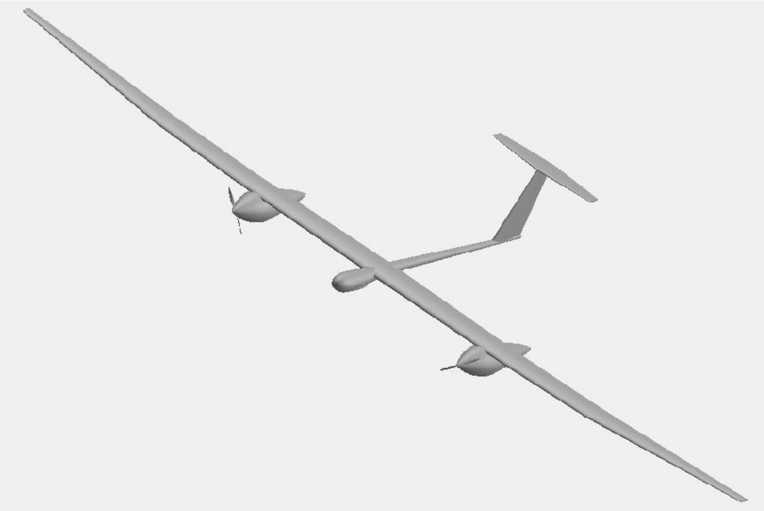
- Gas turbine has significantly better specific power than IC engine
- Relatively low risk propulsion system

Weaknesses

- Growth factor was greater than IC engine concept
- High SFC compared to IC engine
- Has similar issues to IC engine concept with LH_2 fuel and large spot factor

Concept 3

LH_2 Fueled PEM Fuel Cell Powered Wing-Body-Tail



Wingspan	80 / 262	m / ft
Wing Area	260 / 2798	m^2 / ft^2
Wing AR	24.6	-
Wing Loading	18.9 / 3.84	kg/m^2 / lb/ft^2
Fuel Mass	1150 / 2535	kg / lb
Takeoff Mass	4720 / 10405	kg / lb
Loiter Altitude	18 / 59000	km / ft
Loiter Speed	195 / 121	km/hr / mph
Endurance	9.9	days (Comm. Relay)

Strengths

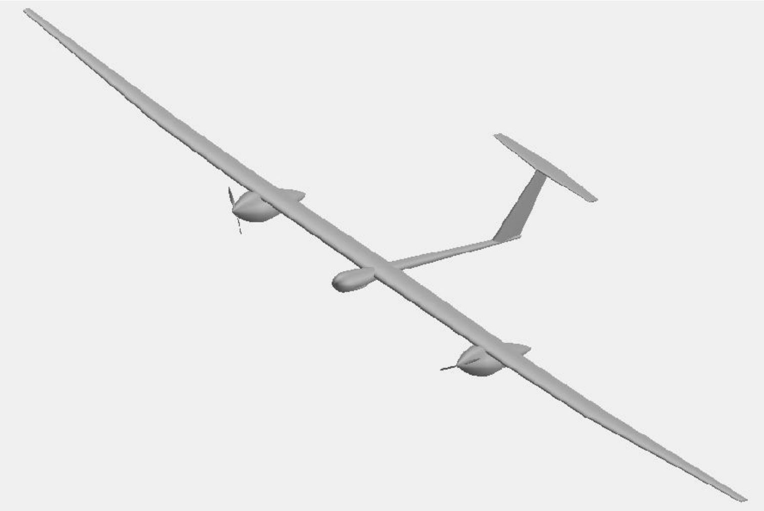
- Excellent endurance, similar to Concept 1 (IC engine)
- Fuel cell has significantly lower SFC compared to the IC engine

Weaknesses

- Relatively high risk propulsion system due to uniqueness and complexity
- Highest growth factor of all wing-body-tail concepts
- Lower specific energy compared to IC engine

Concept 4

LH_2 Fueled Stirling Engine Powered Wing-Body-Tail



Wingspan	80 / 262	m / ft
Wing Area	247 / 2658	m^2 / ft^2
Wing AR	25.9	-
Wing Loading	17.9 / 3.58	kg/m^2 / lb/ft^2
Fuel Mass	1100 / 2425	kg / lb
Takeoff Mass	4220 / 9303	kg / lb
Loiter Altitude	18 / 59000	km / ft
Loiter Speed	188 / 117	km/hr / mph
Endurance	5.8	days (Comm. Relay)

Strengths

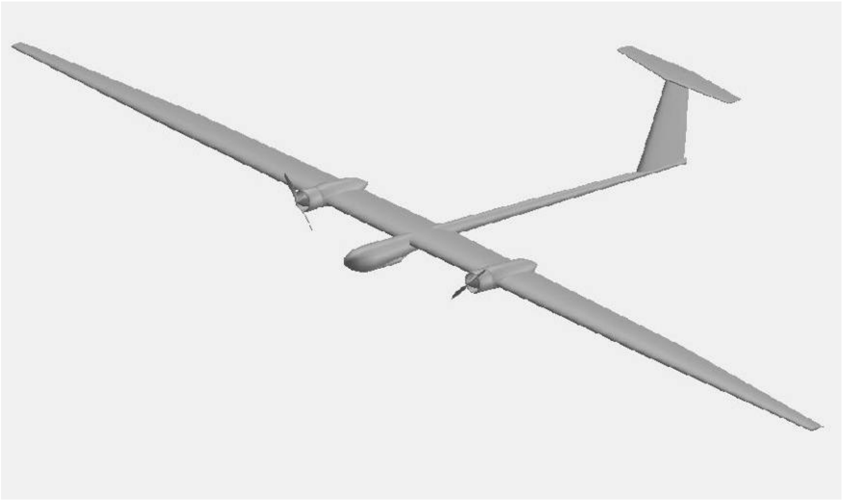
- None

Weaknesses

- Lower specific energy and higher SFC compared to IC engine
- Relatively high risk propulsion system due to uniqueness and complexity
- LH_2 fuel and large spot factor are issues as well

Concept 5

Diesel Fueled IC Engine Powered Wing-Body-Tail



Wingspan	80 / 262	m / ft
Wing Area	267 / 2874	m^2 / ft^2
Wing AR	24.0	-
Wing Loading	19.1 / 3.82	kg/m^2 / lb/ft^2
Fuel Mass	2250 / 4960	kg / lb
Takeoff Mass	4910 / 10825	kg / lb
Loiter Altitude	18 / 59000	km / ft
Loiter Speed	195 / 121	km/hr / mph
Endurance	6.5	days (Comm. Relay)

Strengths

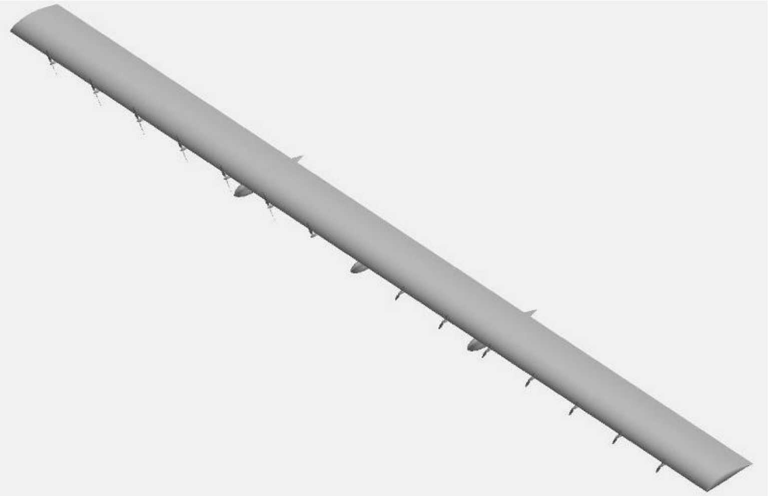
- Overall, a relatively low risk propulsion concept due to conventional propulsion system and fuel

Weaknesses

- Significantly higher SFC compared to LH_2 fueled IC engine
- Largest fuel mass and takeoff mass of any wing-body-tail concept
- Relatively less endurance compared to Concepts 1, 2 and 3

Concept 6

Solar Regenerative Fuel Cell Powered All Wing



Wingspan	100 / 328	m / ft
Wing Area	600 / 6458	m^2 / ft^2
Wing AR	16.7	-
Wing Loading	3.28 / 0.67	kg/m^2 / lb/ft^2
Takeoff Mass	1973 / 4349	kg / lb
Loiter Altitude	18 / 59000	km / ft
$\%P_{regen}$	26	(Comm. Relay)

Strengths

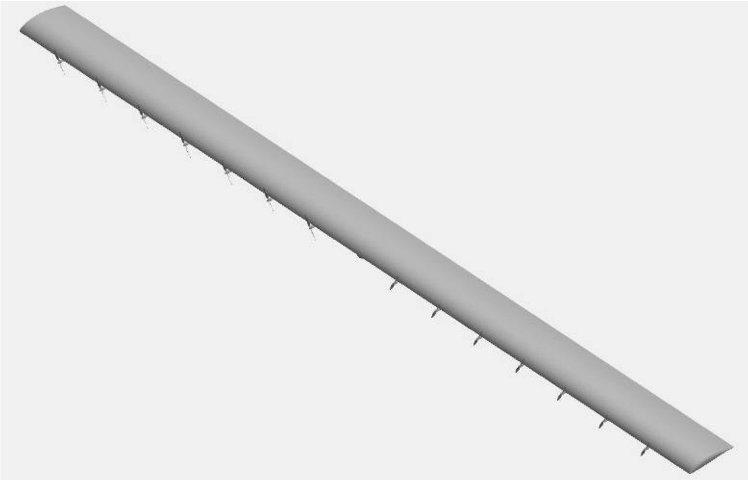
- Heritage in AeroVironment's solar-electric aircraft (Pathfinder, Helios)
- Relatively less complex geometry compared to Concepts 8-10

Weaknesses

- High risk and complex propulsion system
- Technology assumptions for regenerative fuel cell capability do not enable feasible mission
- Highly flexible structure leads to stability and control challenges

Concept 7

Solar Secondary Battery Powered All Wing



Wingspan	100 / 328	m / ft
Wing Area	600 / 6458	m^2 / ft^2
Wing AR	16.7	-
Wing Loading	3.64 / 0.75	kg/m^2 / lb/ft^2
Takeoff Mass	2187 / 4821	kg / lb
Loiter Altitude	18 / 59000	km / ft
$\%P_{regen}$	36	(Comm. Relay)

Strengths

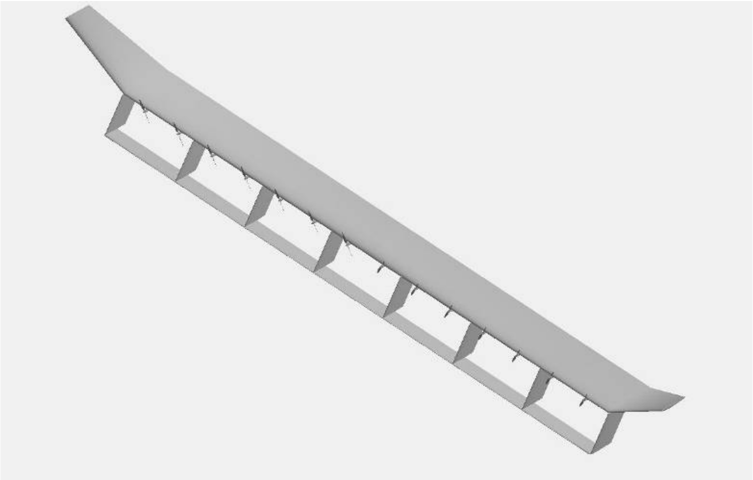
- Similar strengths compared to Concept 6 in terms of planform design
- Secondary battery integration less complex than regen fuel cell
- Relatively better feasibility compared to Concept 6 due to increased efficiency of propulsion system

Weaknesses

- Technology assumptions for secondary battery capability do not enable feasible mission (similar for all solar-regen concepts)
- Highly flexible structure leads to stability and control challenges

Concept 8

Solar Secondary Battery Powered Trussed Wing



Wingspan	97 / 318	m / ft
Wing Area	576 / 6200	m^2 / ft^2
Wing AR	16.3	-
Wing Loading	4.60 / 0.94	kg/m^2 / lb/ft^2
Takeoff Mass	2650 / 5842	kg / lb
Loiter Altitude	18 / 59000	km / ft
$\%P_{regen}$	35	(Comm. Relay)

Strengths

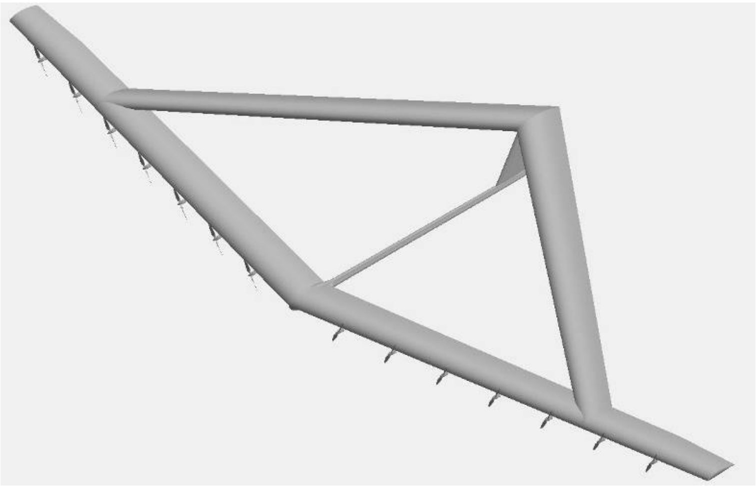
- Relatively rigid structure compared to Concepts 6 and 7
- Vertical solar array area improves solar energy collection capability at mid to high latitudes in winter

Weaknesses

- Increased drag and weight compared to Concepts 6-7
- Shading of the vertical array area during loiter orbit limits additional solar collection capability in most scenarios

Concept 9

Solar Secondary Battery Powered Joined Wing



Wingspan	80 / 56	m
Wing Area	280 / 210	m^2
Wing AR	22.8 / 14.9	-
Wing Loading	3.73 / 0.77	kg/m^2 / lb/ft^2
Takeoff Mass	1830 / 4034	kg / lb
Loiter Altitude	18 / 59000	km / ft
$\%P_{regen}$	29	(Comm. Relay)

Strengths

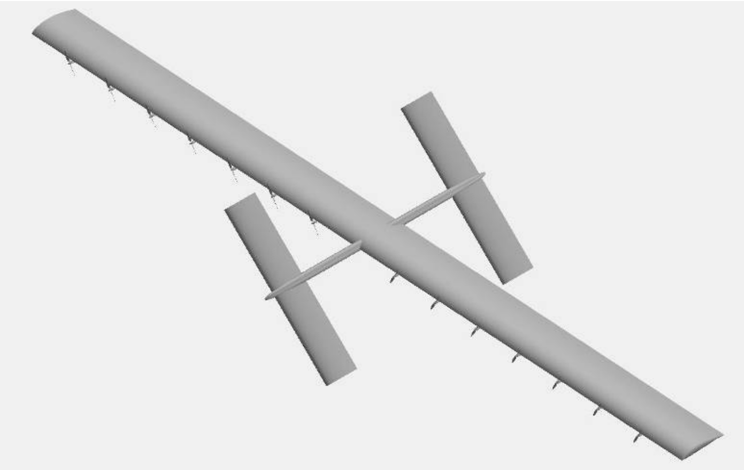
- Reduced span results in a more compact design without sacrificing undue amount of solar array area
- Increased structural rigidity compared to all wing concepts

Weaknesses

- Spot factor was higher than Concept 7 due to nose-to-tail length
- Weight benefit not apparent (all-wing does not have a fuselage or tail)
- Less feasible design when compared to Concept 7

Concept 10

Solar Secondary Battery Powered Multi-surface



Wingspan	100 / 328	m / ft
Wing Area	590 / 6350	m^2 / ft^2
Wing AR	16.9	-
Wing Loading	5.75 / 1.18	kg/m^2 / lb/ft^2
Takeoff Mass	3390 / 7474	kg / lb
Loiter Altitude	18 / 59000	km / ft
$\%P_{regen}$	40	(Comm. Relay)

Strengths

- Increased solar energy collection due to movable auxiliary arrays
- Best feasibility among all solar-regen concepts for this mission (less benefit for hurricane science mission due to latitude and time of year differences)

Weaknesses

- Largest spot factor of all solar-regen concepts due to booms and auxiliary arrays
- Small overall feasibility benefit given increased mass and complexity

A Few Thoughts on Hybrids

- Two types of hybrid propulsion systems considered:
  - Solar augmented consumable system (with and without energy storage)
  - Consumable augmented solar-regen system

- Augmenting a solar-regen system (either heavier or lighter than air) with a consumable auxiliary capability (i.e. adding a small engine/fuel tank to make it through the night) limits system endurance by the very nature of the consumable system (unless air-to-air refueling).

- Augmenting a heavier-than-air consumable system with solar arrays provides only marginal additional endurance. Solar only buys its way on for mission endurances of multiple weeks.

HTA Solar-Regen Trade Studies

Mission Trade Study: ***What are HTA SR HALE mission capabilities given current technology?***

- Determine the mission capabilities of a baseline, near-term technology HTA SR vehicle
- Evaluate sensitivity of mission feasibility to mission requirements
- Explore potential trade-offs among mission requirements

Technology Trade Study: ***What technology areas need investment to realize desired future capabilities?***

- Determine technology advances required to enable threshold missions
- Evaluate sensitivity of mission feasibility to technology assumptions
- Identify technology areas most important to mission feasibility

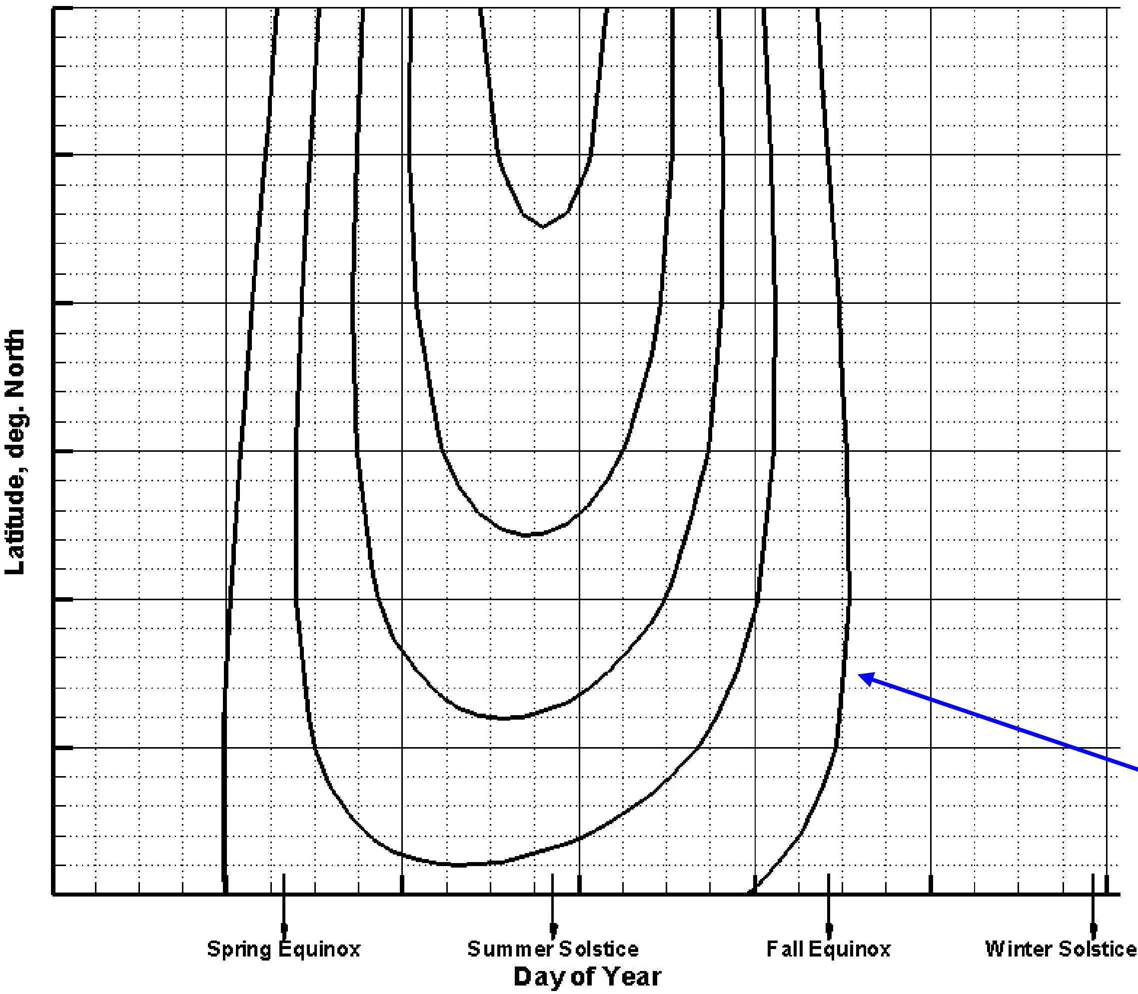
Mission Trade Study

- Establish bounds of mission feasibility for heavier-than-air, solar-regen configurations given near-term technology assumptions
- Six mission parameters examined:

Mission Requirement	Range Considered
Latitude	15° North to 50° North
Day of Year	1 to 365
Payload Mass	0 to 200 kg
Payload Power	0 to 4 kW
Loiter Altitude	15 to 18 km
Minimum Dash Speed	25 to 45 m/s

- Required use of surrogate model (response surface) for analysis
  - 1000's of points for comprehensive mission requirements study
  - Optimization of wing area needed due to varying requirements (span fixed at 100m)
  - Full analysis takes 1.5-2 minutes per "function evaluation"

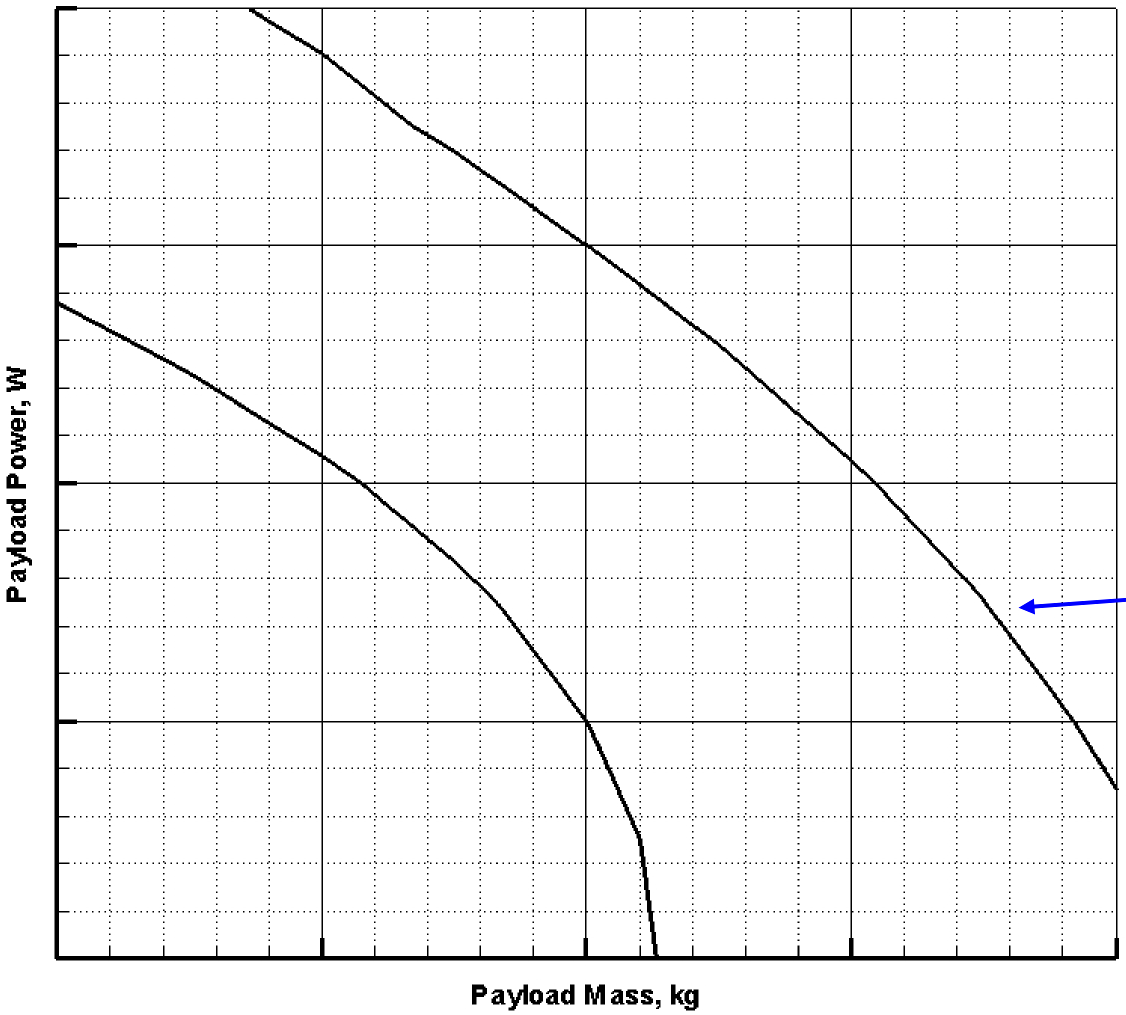
Payload Mass Feasibility Contours



- **Payload mass, latitude, and day of year varied; other requirements at minimum values**
- **Contours are locus of points with %Pregen=100**
- **Large sensitivity of latitude and day of year capability to payload mass requirement**

Varying Payload Mass contours for feasible mission

Payload vs. Altitude Trades



- **Payload power, payload mass, and altitude varied; other requirements at best case values**
- **Contours are locus of points with %Pregen=100**

Varying Loiter Altitude contours for feasible mission

Technology Trade Study

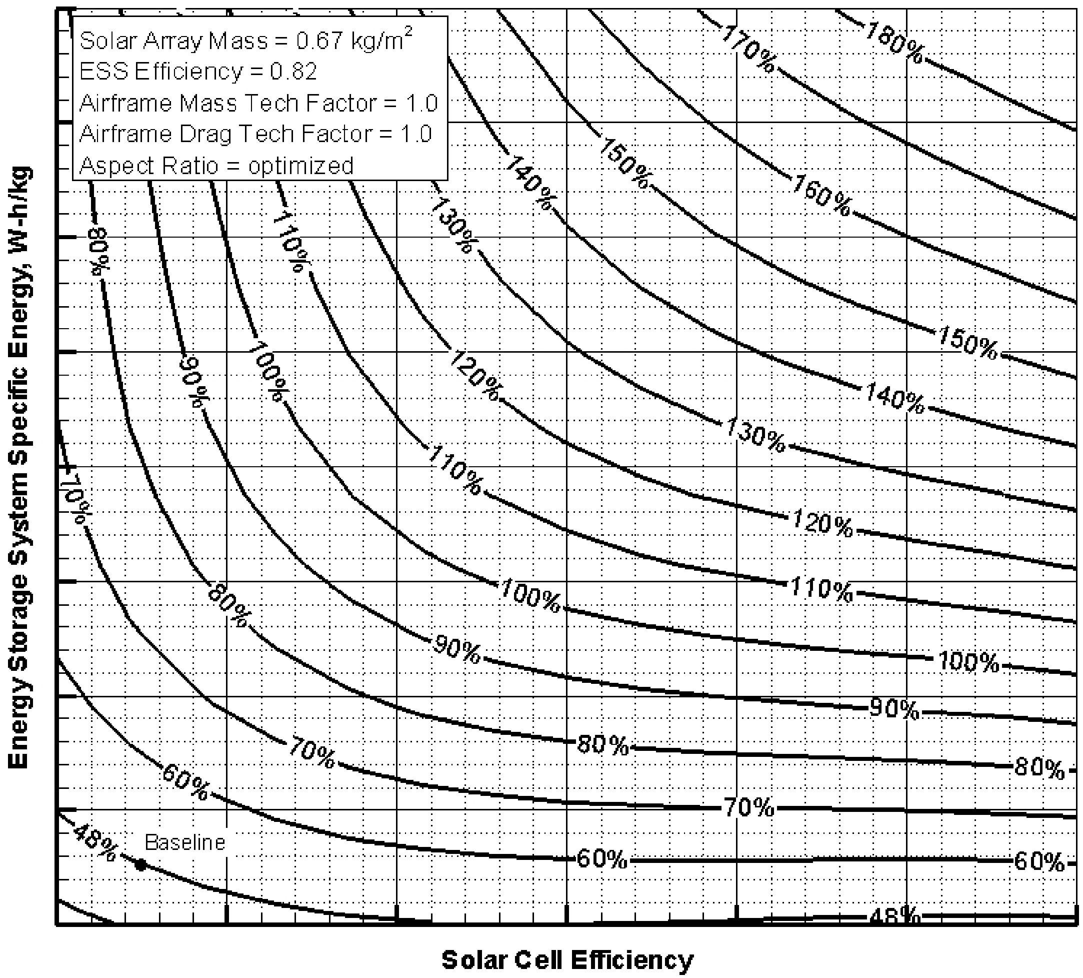
- Determine where to focus research and development efforts to enable desired mission capabilities
- Separate studies conducted for hurricane mission and communications relay mission
- Surrogate models developed using response surface methodology as in mission trade study

	Range Considered	
Technology Area	**Hurricane Science**	**Comm. Relay**
Solar Cell Reference Eff.	0.10 to 0.75	0.10 to 1.0
Solar Array Mass	0 to 1.5 kg/m^2	0 to 1.5 kg/m^2
ESS* Roundtrip Efficiency	0.3 to 1.0	0.3 to 1.0
ESS Specific Energy	100 to 1000 W-h/kg	100 to 1500 W-h/kg
Airframe Mass	-25% to +50%	±50%
Airframe Drag	-25% to +50%	±50%

* Energy Storage System (ESS)

Technology Interactions

Solar Cell Efficiency vs. ESS Specific Energy for Hurricane Science Mission

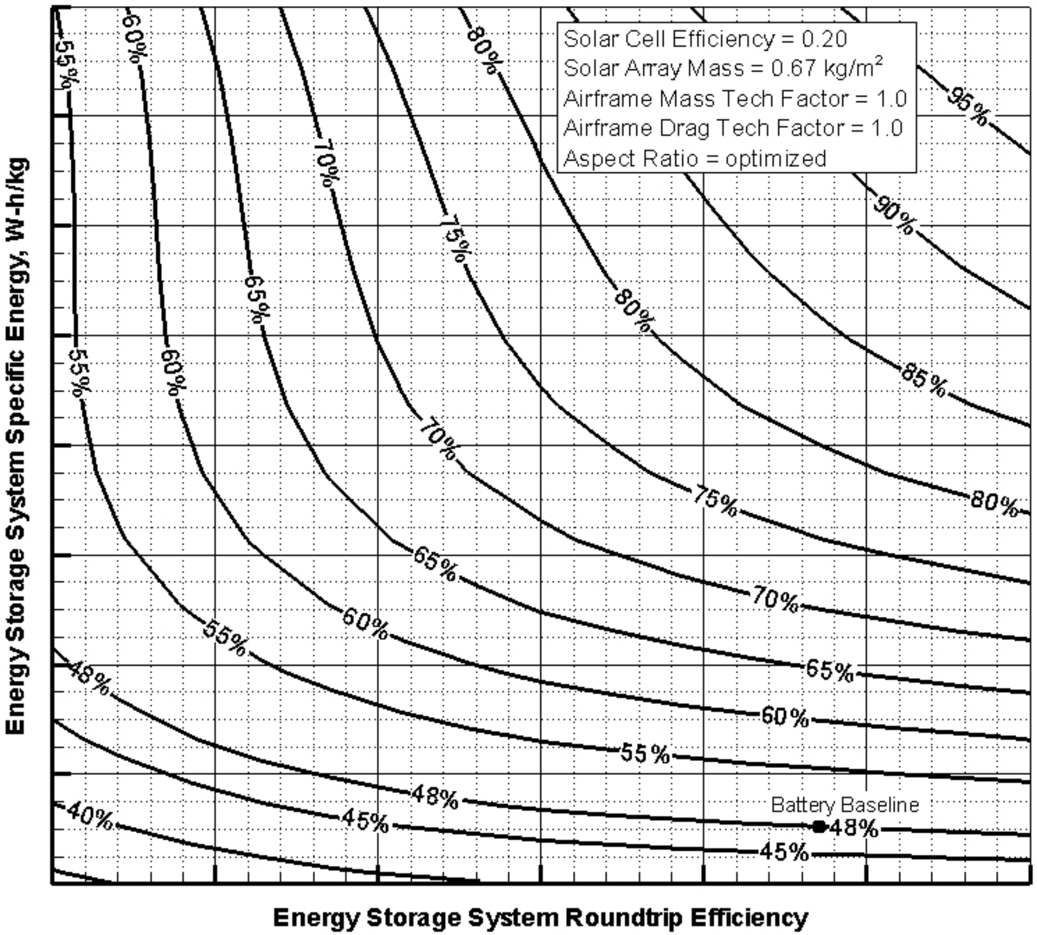


Hurricane Science Mission
%Pregen Contours

- **Solar array mass, ESS efficiency, airframe mass and drag tech. factors at baseline values**
- **Increases in both solar cell efficiency and ESS specific energy required for mission feasibility, if improvement occurs in only one area a point of "diminishing returns" is reached:**
- **At low ESS specific energies, increases in solar cell efficiency do not increase mission feasibility**

Technology Interactions

ESS Efficiency vs. ESS Specific Energy for Hurricane Science Mission



Hurricane Science Mission %Pregen Contours

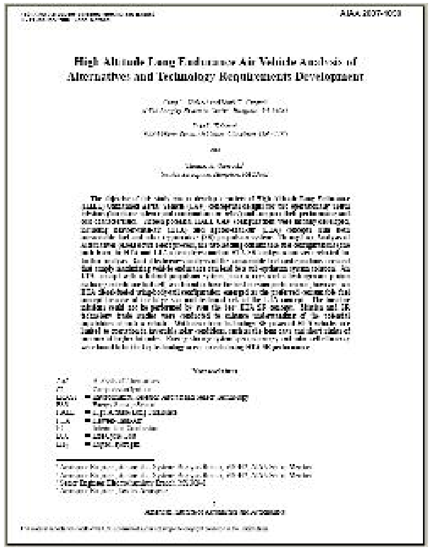
- **Solar array mass, efficiency, airframe mass and drag tech. factors at baseline values**
- **Increases in both ESS efficiency and ESS specific energy required for mission feasibility, if improvement occurs in only one area a point of "diminishing returns" is reached:**
- **At low ESS specific energies, increases in ESS efficiency do not increase mission feasibility**

Potential Adv. Technology Solutions

		Technology Set Enabling Mission Feasibility	
Technology Area	**Baseline Value**	**Hurricane Science Mission**	**Comm. Relay Mission**
Solar Cell Reference Eff.	20%	35%	45%
Solar Array Mass	0.67 kg/m^2	0.80 kg/m2	0.40 kg/m2
ESS Roundtrip Efficiency	82%	90%	90%
ESS Specific Energy	252 W-h/kg	500 W-h/kg	750 W-h/kg
Airframe Mass Tech Factor	1.0	0.9	0.75
Airframe Drag Tech Factor	1.0	1.0	0.85

- **Infinite possible combinations of technology advances which will enable mission feasibility, one combination shown for each mission (values do not represent any specific technologies)**
- **Very aggressive technology assumptions required for communications relay mission, airframe improvements as well as propulsion improvements are needed**

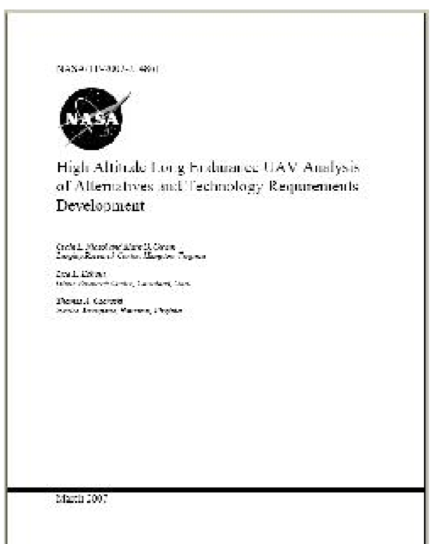
Publication Information



AIAA 2007-1050

High Altitude Long Endurance Air Vehicle Analysis of Alternatives and Technology Requirements Development

- AIAA 2007-1050
- Presented at AIAA Aerospace Sciences Meeting in January 2007
- 17 page study summary
- Available through AIAA or NASA Technical Reports Server (http://ntrs.nasa.gov)



High Altitude Long Endurance UAV Analysis of Alternatives and Technology Requirements Development

March 2007

- NASA TP 2007-214861
- Published 3/07
- 111 page detailed report
- Available through NASA Technical Reports Server (http://ntrs.nasa.gov)

Questions?

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Hampton, VA 23681-0001

Autonomous Aerial Refueling Demonstration (AARD)

Lt COL Jim McCormick
DARPA/TTO

Autonomous Air Refueling Demonstration

First fully autonomous air refueling
30 August 2006

VULTURE Industry Day, 7 Jun 2007

LtCol Jim McCormick

Autonomous Airborne Refueling Demonstration (AARD)

DARPA Initiative

- **High Risk / High Payoff**
- **Feasibility Demonstration**
- **Address Unique Challenge of Probe and Drogue**

Objectives

- **“Take the Technical Excuse Off the Table”**
- **Demonstrate in Operationally Representative Conditions**

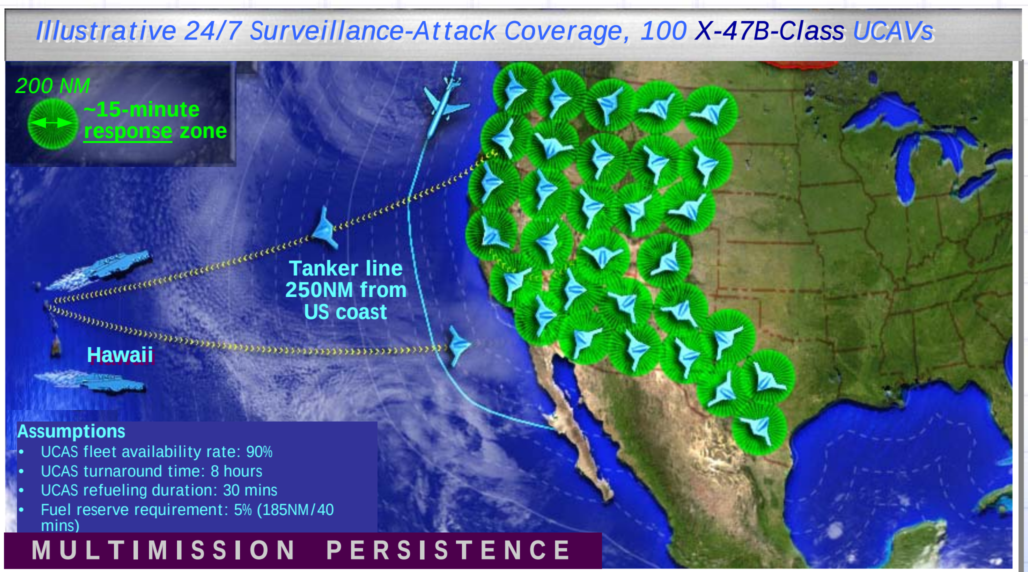
Autonomous Refueling in Action

Automated Air Refueling Mission Considerations

AARD is Essential for Extended Unmanned Ops
AARD can Enhance Manned Operations
Air Refueling Enables Ultra-Long Endurance Ops

AR Advantages
- **Range and endurance**
- **Flexibility**
- **Tanker Efficiencies**

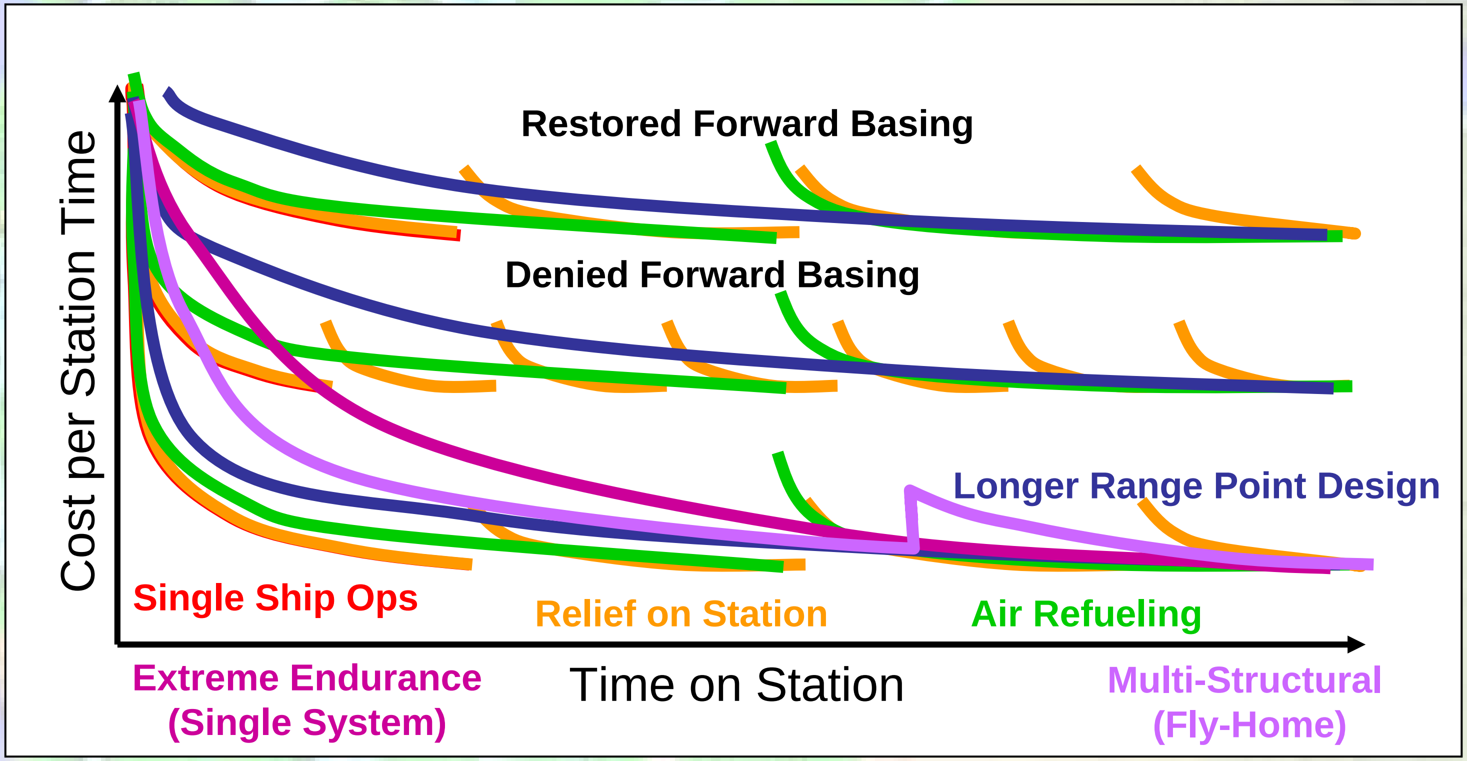
AR Challenges
- **Delivered Fuel Cost**
- **Limited Resource**
- **Tanker Access**
- **Generally Refuel Off-Station**



Complementary Enablers
- **Relief on station**
- **Longer range airframe**
- **Forward basing**
- **Reduced cost basing**
- **Regenerative power**
- **Power Transmission**
- **Space Operations**
- **Multi-Structural Aero**

Persistence – A Thought Experiment

- Unity
- Mass
- Economy
- Initiative
- Surprise
- **Persistence**



Relative costs are artificially neutral

Specific details will impact relative cost – economies of scale, tanker to receiver ratio, mission specialization

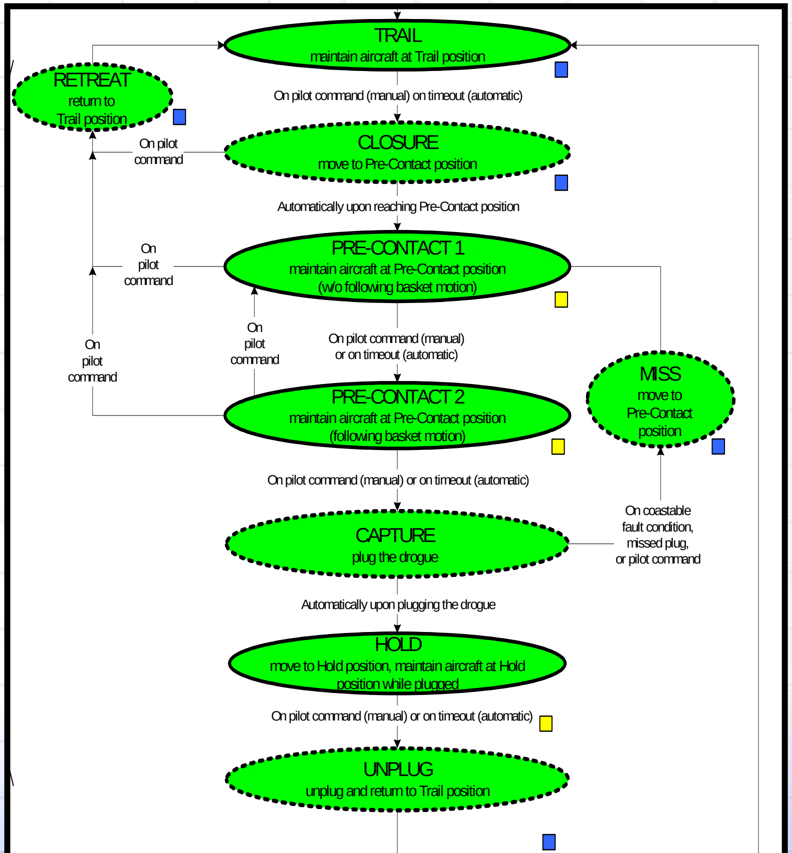
Quality of station time is not necessarily comparable

Technical Approach

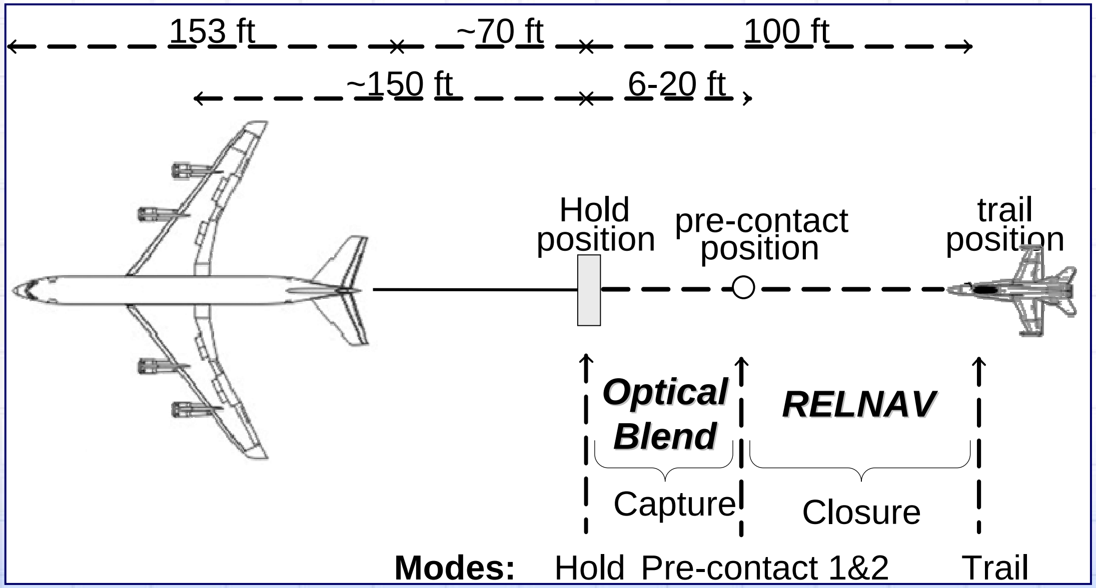
Sierra Nevada Autonomous Controls
NASA Dryden F/A-18 Surrogate UAS
Octec Video Tracking System
Omega Commercial Tanker

Error Budgets

- **Drogue Capture (Lateral and Vertical)**
  - +/- 5.00 in sensor error (2 sigma)
  - +/- 10.36 in control error (2 sigma)
  - +/- 11.50 in total error to plug
    32" basket with 95% success
- **Station Keeping / Hold**
  - +/- 6.56 ft lateral & vertical (2 sigma)
  - +/- 9.80 ft longitudinal (2 sigma)

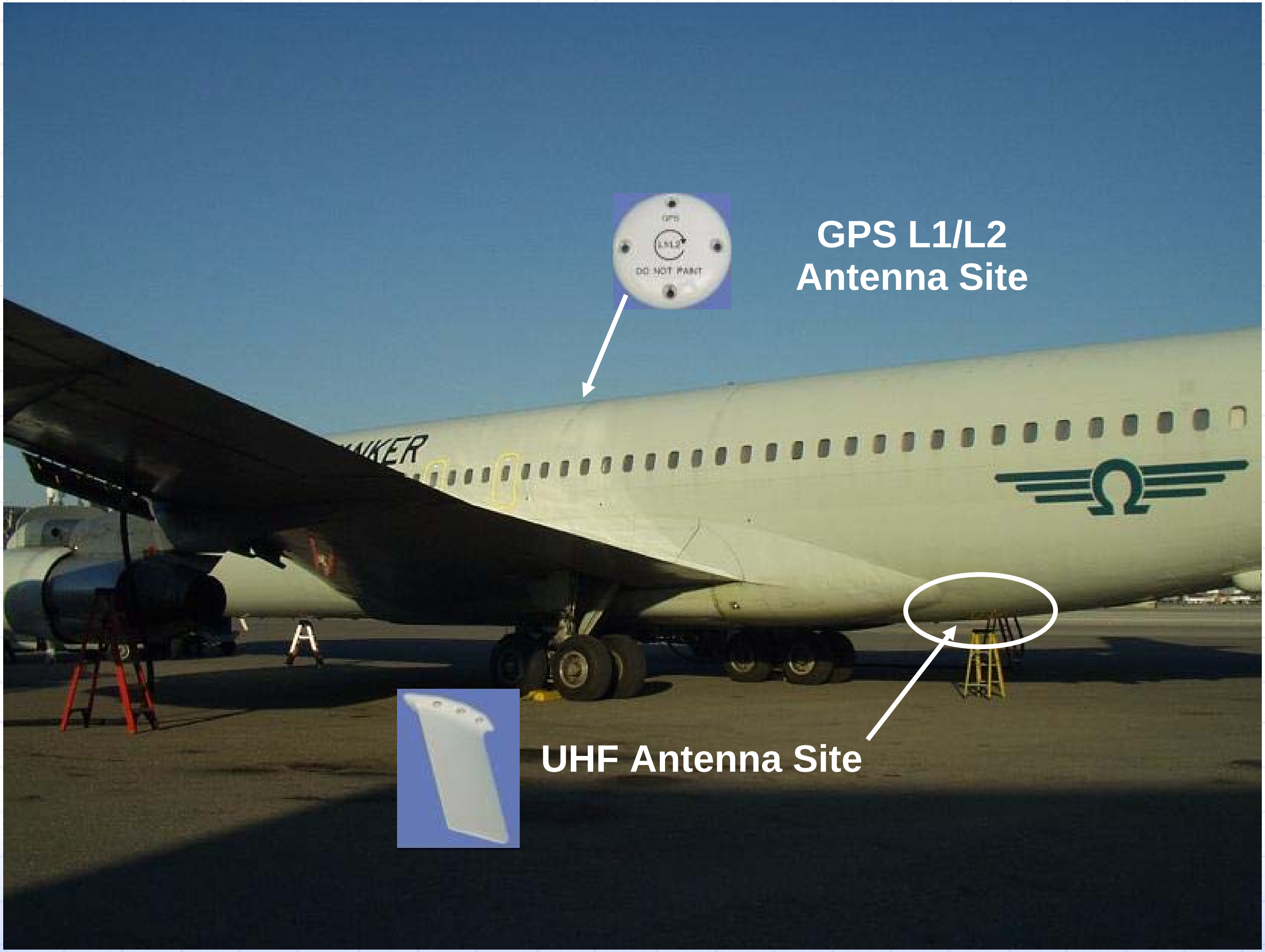


Multiple control innovations left on the table

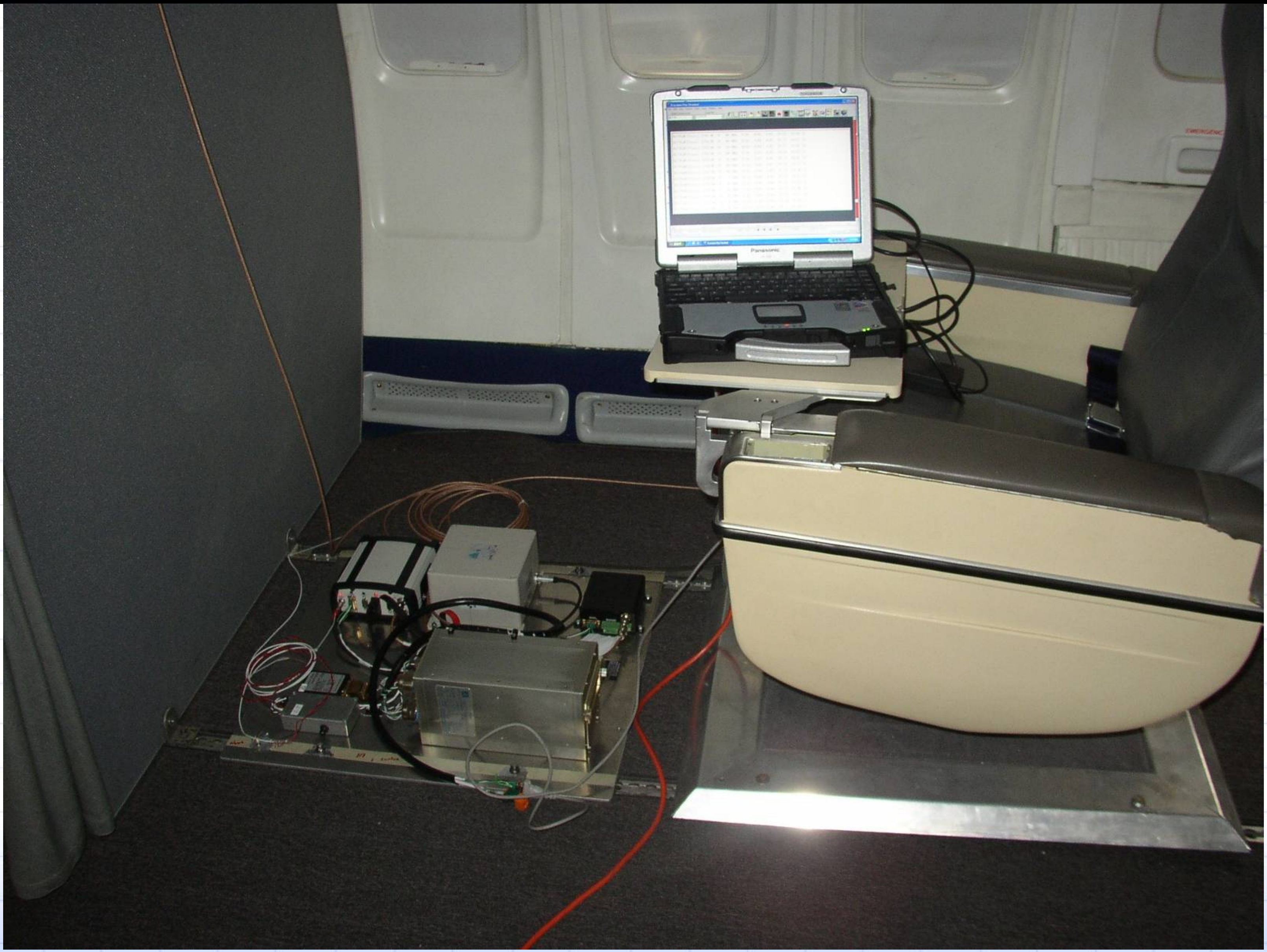


Autonomous Refueling in Action

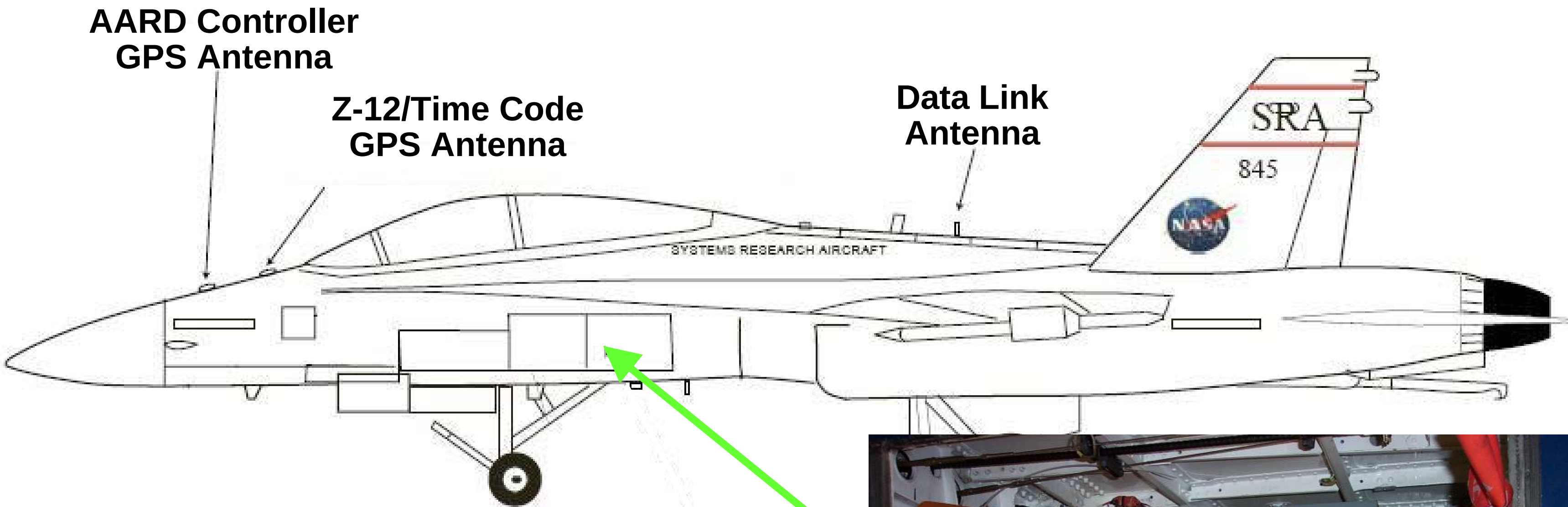
No Modifications to Refueling Systems



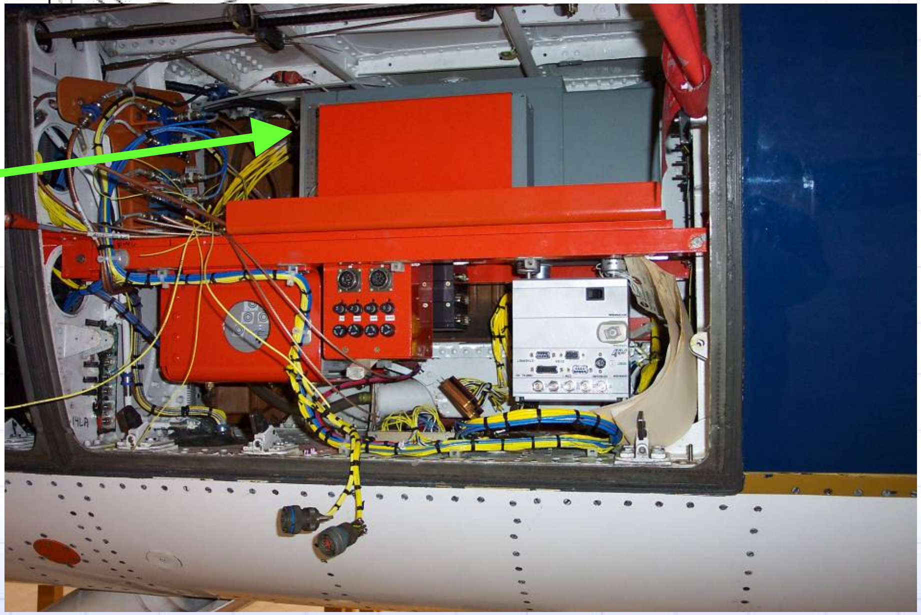
Small Footprint COTS Inertial / GPS / Comms



F/A-18 Installation



AARD Controller



Cockpit Installation

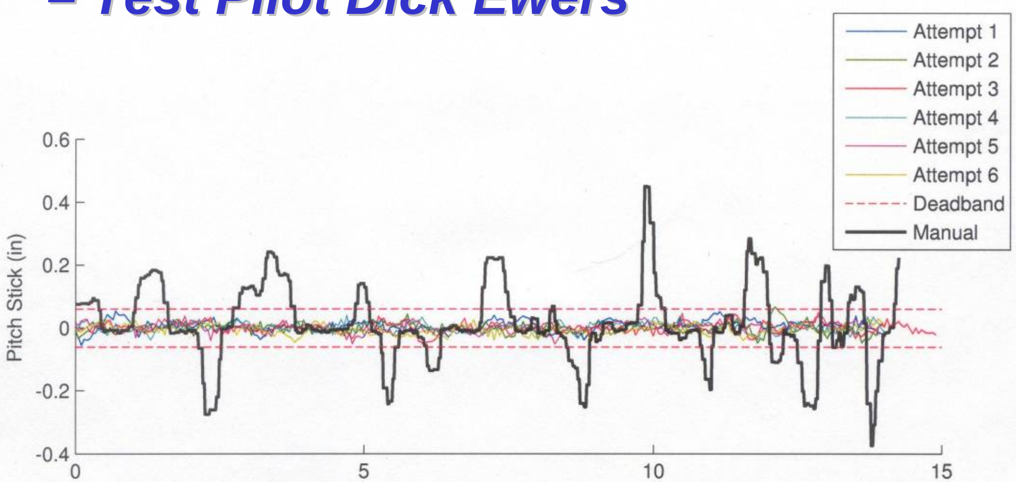
Results

Kickoff - 1 Mar 05

"This computer approach was unbelievably stable and smooth"

"Very well-behaved miss response"

– Test Pilot Dick Ewers



Comparison of Flight Control Command Inputs

Numerous additional control innovations available, but not used for AARD

Feasibility

- **Stable formation flight**
  - **→"Boom Ready"**
- **Reliable optical track**
- **Graceful "miss" management**
- **First-ever auto plug**

Operational Conditions

- **Extended rendezvous**
- **Turbulence**
- **Plug in a turn**
- **Improved optical track**

Autonomous Refueling in Action

Results

14 flights completed at Edwards Air Force Base

Autonomous station keeping

- Pre-contact position, straight and level and through turns

1st autonomous refueling engagement 30 Aug 06

Autonomous rendezvous

Autonomous drogue capture & unplug during turns

- Both left and right turns

Transferred fuel during level flight and turns

- up to 2 nmi behind and 500 ft below, different headings

Engagement in turbulence

- >3 foot vertical drogue motion
- Ability to track through drogue motion

Autonomous Refueling in Action

Automated Air Refueling Platform Considerations

Advantages

- **Improved Safety**
- **Reduced Training**
- **Expanded Envelope**
- **Reduced Crew Workload**
- **Novel Installations**

Challenges

- Reliability
- **Fault Tolerance**
- **Integration**
- **Crew Resource Management**

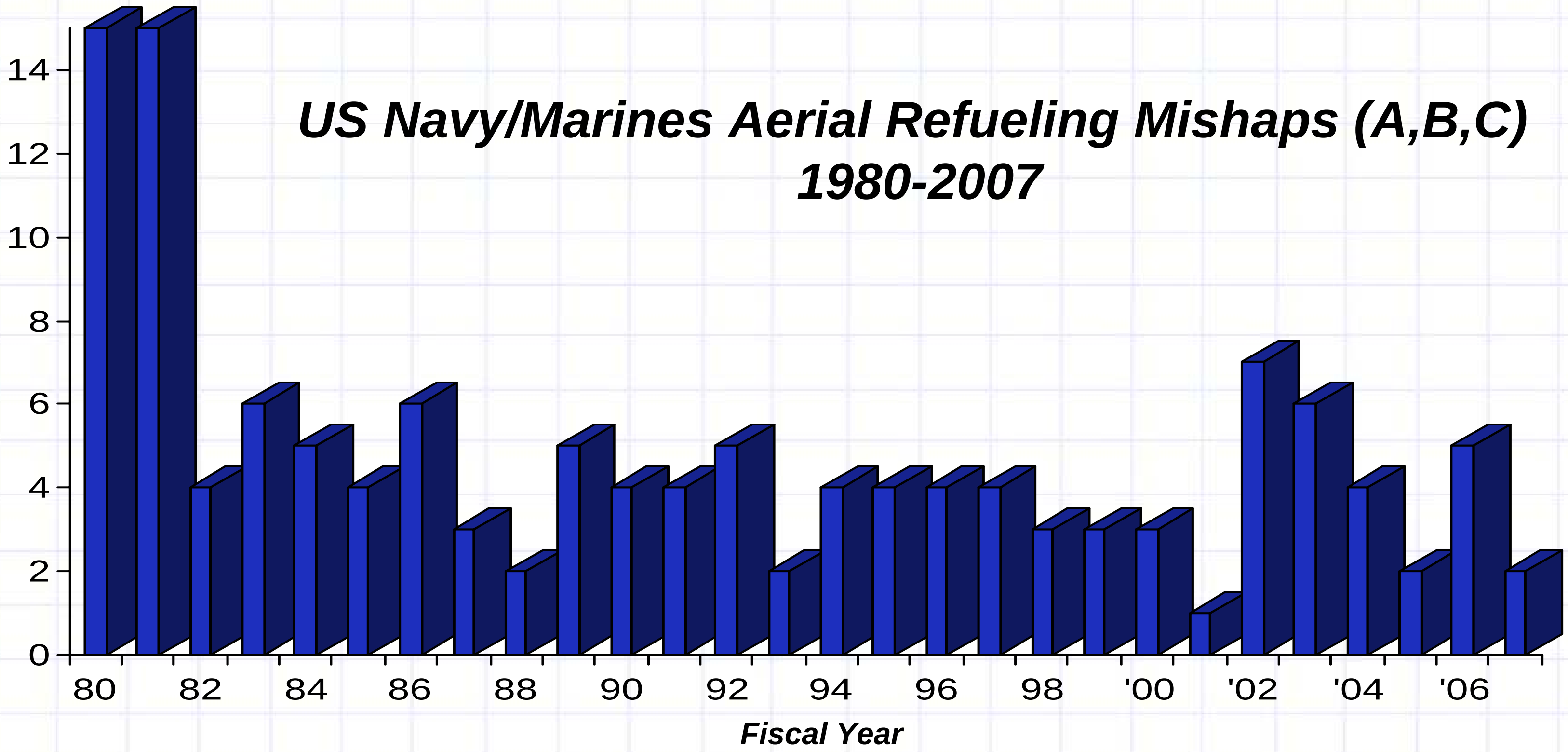
Refueling Hall of Pain

1 mishap per 3,750 refueling events, estimated from FY97-06 F-14 and F/A-18 mishap data

Opportunities

- **Service Fluids**
- **Load Weapons/Sensors**
- **Inspect/Adjust Systems**
- **Replace Components**

Refueling Safety Experience



10 of 140 mishaps are Class A (> $1M or loss of life)

Source: Naval Safety Center

US Navy/Marines FY 2006-2007 Aerial Refueling Mishaps (7 Total)

Class "A"

None

Class "B"

25 OCT 05: CH-53 Blades strike hose, rotor is damaged. Tanker successfully guillotines damaged hose.

Class "C"

08 OCT 05: AV-8B suffers canopy damage from basket.

26 OCT 05: F-18C suffers probe assembly and windscreen damage from basket.

13 FEB 06: F-18F damages probe and fuselage from basket.

23 AUG 06: F-18C Windscreen, top of LEX and fuselage skin damaged. (OMEGA)

14 DEC 06: F-18E Probe severed by MIPR pod.

02 FEB 07: F-18F Engine FOD after basket slap to aircraft.

Source: Naval Safety Center

US Air Force FY 2006-2007 Aerial Refueling Mishaps (16 of 27)

Date - Location	Class	Receiver	Rapid Closure	Breakaway Called	Remarks
12 Oct 05 - US	C	F-16	N	Y	Inner Limit
*28 Oct 05 - US	A	F-16	Y	Y	Boom Struck F-16 Fuselage
8 Nov 05 - US	C	F-16	Y	Y	Called Breakaway Too Late
25 Nov 05 - OEF	C	C-17	Y	Y	Heavy Wt A/R
30 Nov 05 - US	C	E-6	Y	N	Unstable Rcvr
5 Dec 05 - US	C	F-117	Y	Y	Unstable Rcvr, Inner Limit
21 Dec 05 - US	C	F-16	N	Y	Unstable Rcvr, Inner Limit
22 Dec 05 - US	C	C-17	Y	Y	Unstable Rcvr
9 Feb 06 - US	C	F-15	N	N	Backed Out Prior To Disconnect
28 Mar 06 - US	C	F-16	Y	Y	Inner Limit/Lower Limit
22 Apr 06 - OEF	C	A-10	N	Y	Lower Limit/BFD
25 Apr 06 - US	C	F-15	Y	Y	Inner Limit
24 Apr 06 - US	C	C-17	Y	Y	Inner Limit/BFD
3 May 06 - US	C	C-17	N	Y	Inner/Lower Limit/BFD
10 May 06 - Cor	C	B-52	N	Y	Inner/Lower Limit/Sun Glare/VDL
11 May 06 - Cor	B	KC-10	N	Y	Lower Limit/No Downforce/BFD

*Denotes KC-10 Mishaps

Source: AMC Flight Safety

US Air Force FY 2006-2007 Aerial Refueling Mishaps (27 Total)

Date - Location	Class	Receiver	Rapid Closure	Breakaway Called?	Remarks
16 May 06 - US	B	F-15E	Y	Y	F-15 Signal Amp Failed/Inner Lmt.
6 Jun 06 - JA	C	F-15	N	N	Inner Limit/Delayed Disconnect
*29 Jun 06 - US	C	C-17	N	Y	BFD
29 Jun 06 - US	C	F-15	Y	Y	Inner Limit
11 Jul 06 - OEF	C	B-1B	Y	Y	BFD
21 Jul 06 - US	C	F-15	Y	Y	Inner/Lower Limit, BFD
2 Aug 06 - US	C	?	?	?	Boom damage
14 Aug 06 - US	C	KC-10	Y	Y	Nozzle Binding, BFD
25 Aug 06 - US	C	F-16	Y	N	Boom damage/antenna damage
26 Aug 06 - US	C	?	N	N	Unknown Rcvr @ Red Flag
20 Sep 06 – OIF	B	KC-10	N	Y	AP Disc/Nose Ovr/Boom Strike 135

*Denotes KC-10 Mishaps

Key:

US = In US on training sortie

Cor = Coronet (Deploy/Re-deploy)

OEF = Operation Enduring Freedom

VDL = VHF Data Link Antenna

JA = In Japan on training sortie

OIF = Operation Iraqi Freedom

BFD = Brute Force Disconnect

Source: AMC Flight Safety

US Air Force FY 2006-2007 Air Refueling Mishap Causal Factors

Primary Causes

1. Rapid Receiver Closure (Closing > 3-5 feet per second)
2. Boom Operators Calling Breakaway Too Late or Not at All
3. Receivers Exceeding Refueling Envelope Limits, Causing Nozzle Binding & Subsequent Inadvertent or Deliberate Brute Force Disconnect
4. Boom Operators Not Disconnecting or Calling Breakaway Prior to Receivers Exceeding Envelope Limits
5. Instructor Pilots/Boom Operators Late to Intervene

Secondary Causes

1. Improper Energy Management by Heavyweight Receivers
2. Receivers Not Attaining a Zero Rate of Closure in Pre-Contact
3. Boom Operators Making Contacts w/Closing Receivers
4. Sun Glare
5. Boom Operator Experience Levels (Many Cross-Flows)

Source: AMC Flight Safety

Conclusion

Autonomous Air Refueling Is Here Today

- **Unmanned system developers can, with confidence, count on the benefits of air refueling proven so powerful for manned aviation**
- **Commensurate levels of reliability are needed to support extreme endurance missions**

Autonomous Air Refueling for Manned Aviation

- **Automation promises to enhance the effectiveness and safety of manned air refueling**

Autonomous Air Refueling Marks the Start of a Revolutionary Leap Ahead in Military Persistent Access

- **AAR is key to achieving the unprecedented level of access required to succeed in an increasingly complex defense environment**

Lunch

Briefing Website:

http://www.darpa.mil/tto/solicitations.htm

Program Plan

Dr. Wade Pulliam
DARPA / TTO

VULTURE Program Requirements

Full-Scale System Non-Tradable Requirements

- **Requirement 1 - Payload**
  - 1000 lbs
  - 5kW
- **Requirement 2 - Reliability**
  - 5 year endurance aircraft for a single payload
  - Design loiter speed to allow 99+% time-on-station
    - Maintain useful position to point of interest
- **Must be airborne flight; No buoyant flight**
- **No radioactive power solutions**

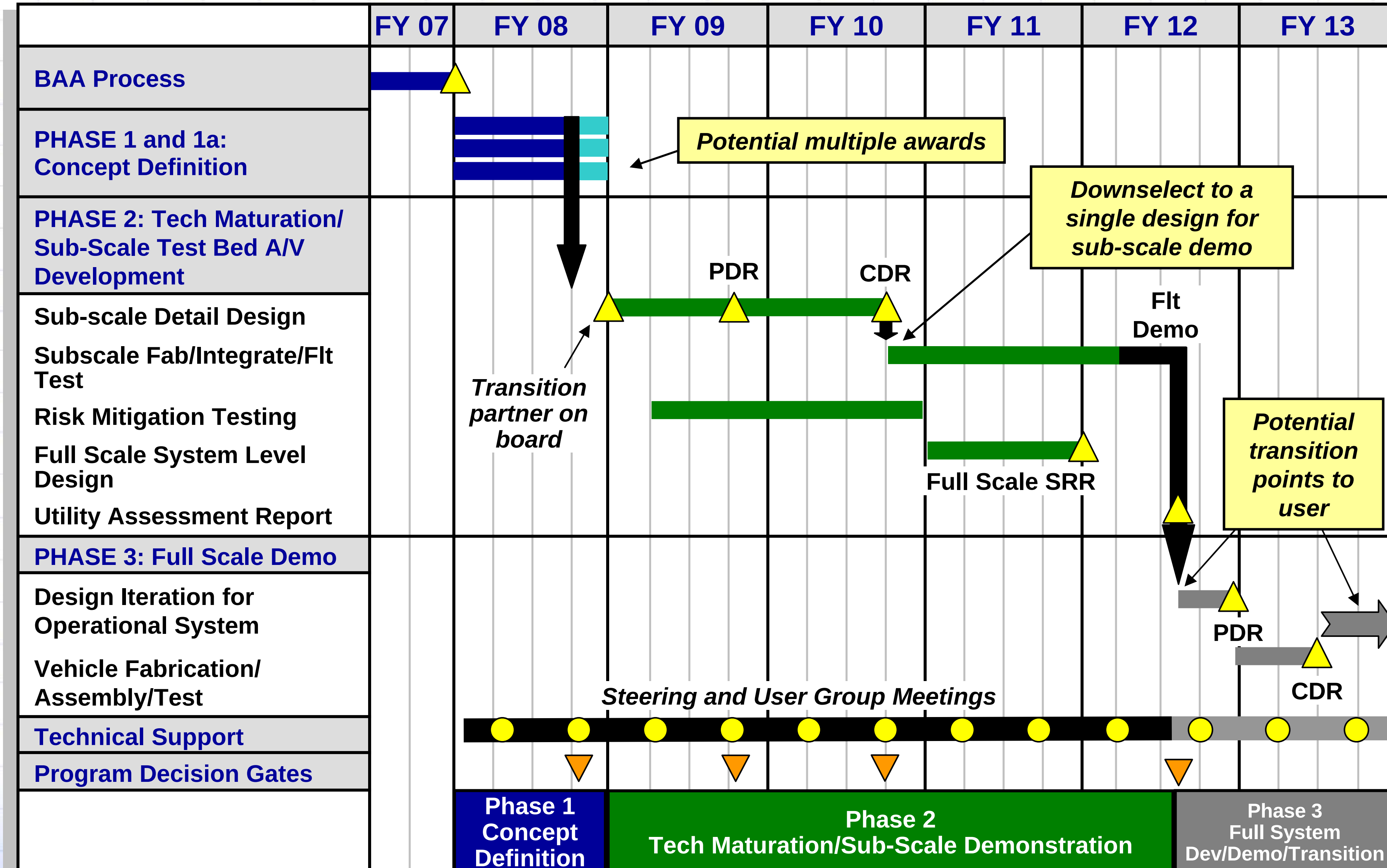
System Level Attributes

- **Unmanned system**
- **Autonomous**

Tradable Goals

- **No altitude or geographical coverage (latitude) requirement**
  - Will be based on contractor military utility study
- **Demonstration system shall be traceable to the Full-Scale System Concept**

Notional Program Plan

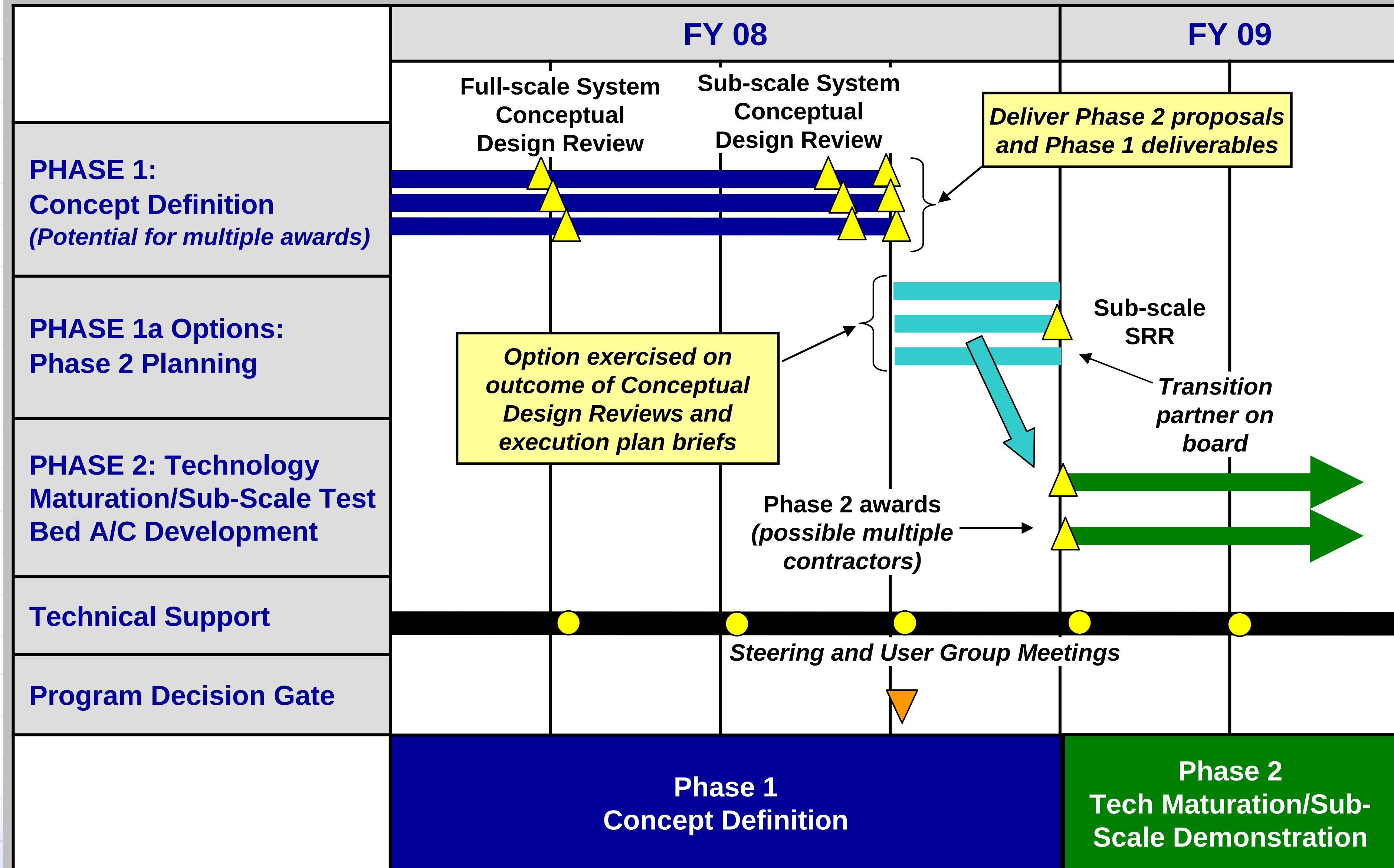


VULTURE Phase I Program Plan
(Timeline is Notional)

Phase 1 - Design Studies (9-12 months)

- **Objectives**
  - Generate a System Level Design that closes around the BAA requirements
  - Conduct a formal reliability and mission success assessment of the design at the subsystem level
  - Develop ConOps/military utility assessment of the proposed system
  - Develop a credible development program to reach the proposed system capability within the Phase II and Phase III timeframes
- **Programmatics**
  - 3rd month after award: Full-Scale System Conceptual Design Review
  - 8th month after award: Sub-Scale System Conceptual Design Review
  - 9th month after award: detailed Phase II & III Execution Plan
  - Phase 1a Option: a 3 month duration following month 9 to work toward a Sub-Scale System Requirements Review (SRR)
- **Deliverables**
  - Full-scale system Conceptual Design Review data package (3 months after contract award)
  - Sub-scale system Conceptual Design Review data package (9 months after contract award)
  - Sub-Scale SRR data package (12 months after contract award)
  - 9th month after award: Updated Phase II Technical and Cost proposal (WBS level 4 details), Updated Phase III Technical and Cost proposal (WBS level 3 details)
- **Criteria for Following Phase**
  - Closed design
  - Credible Phase II technical and mission success plan
  - Identification of transition partner

Notional Phase 1 Schedule

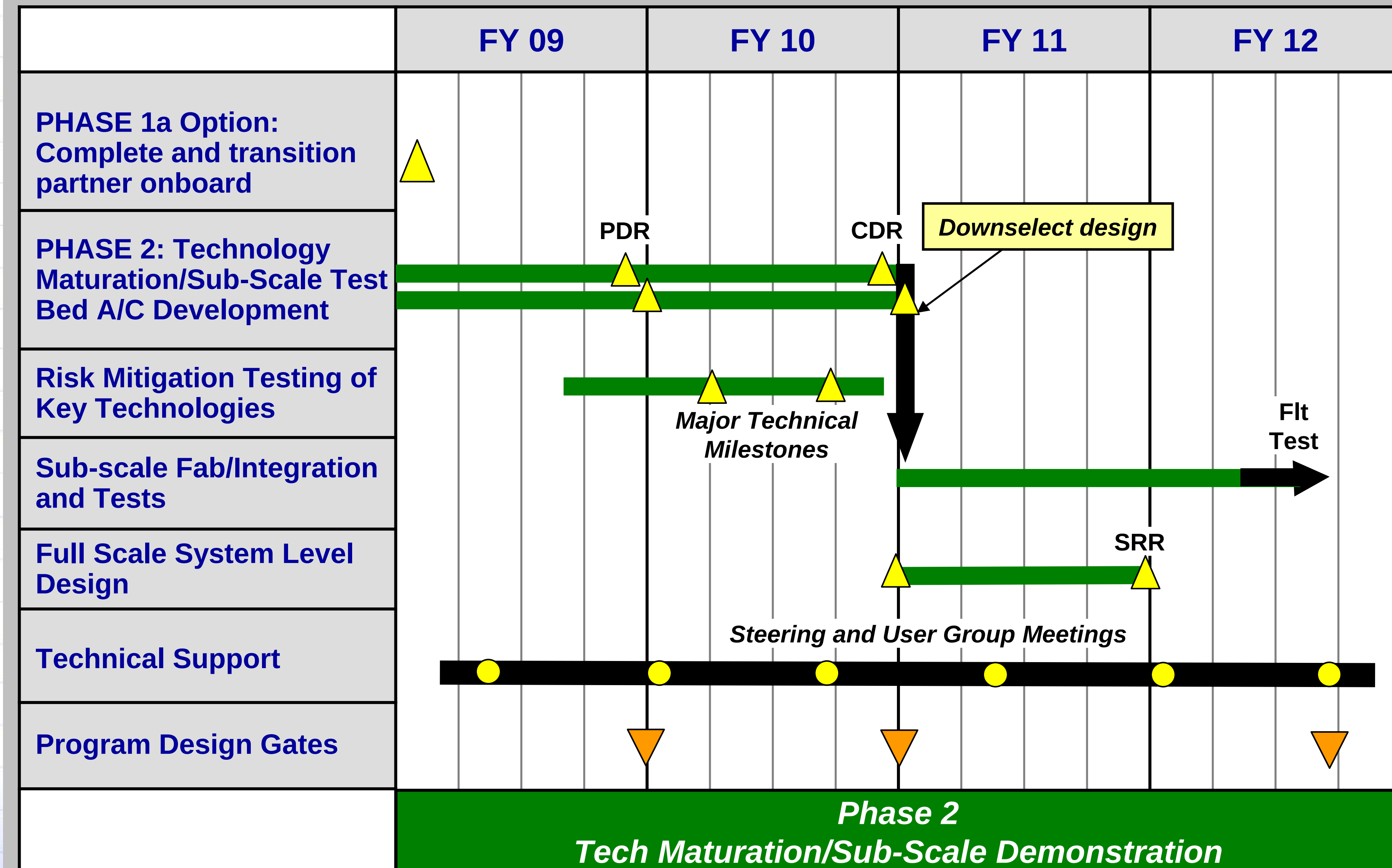


VULTURE Phase II Program Plan
(Timeline is Notional)

Phase 2 - Subscale System Demonstration

- **Objectives**
  - Develop a detail design and flight test a Sub-Scale Flight vehicle system to mature technological issue and reduce risk for the full scale demonstration vehicle
  - Experimentally verify major sub-system reliability and total system mission success goals
  - Determine remaining technology maturation issues
  - Develop a SRR package of the Full-Scale demonstration system configuration
  - Finalize ConOps/military utility assessment
- **Programmatics**
  - CDR ~ 24 months from Phase II start
  - Sub-scale first flight ~ 41 months from Phase II start
  - A detailed Phase III Execution Plan
- **Deliverable**
  - Sub-Scale PDR and CDR
  - Sub-Scale performance/mission simulation model (6-DOF)
  - A Full-Scale demonstrator SRR package
  - An updated Phase III technical and cost proposal to WBS level 4 details
  - Sub-Scale flight test demonstration of a 150 lb, 750 W payload for 3 month continuous
- **Criteria for Following Phase**
  - Flight of sub-scale system demonstrating critical technologies and operations

Notional Phase 2 Schedule



VULTURE Phase III Program Plan
(Timeline is Notional)

Potential Phase 3 - Full Scale System Demonstration (~36 months)

- **Objective**
  - Build and demonstrate a full scale 5-year flight system
- **Programmatics**
  - CDR in ~ 12 months from Phase III start
  - Full-scale first flight ~ 36 months from Phase III start
- **Deliverable**
  - Full-scale PDR and CDR
  - Full-scale flight test for 12 months continuously
- **Significant participation by transition customer**
- **Transition aircraft to partner during flight test**

Tentative Acquisition Schedule

Industry Day	07 June 2007
BAA Release	21 June 2007
Proposals Due	7 Aug 2007
Evaluation Complete	7 Sep 2007
Negotiations & Awards	Oct 2007

http://www.darpa.mil/tto/solicitations.htm

Tentative Acquisition Overview

BAA Response Anticipated to Include:

- **Executive Summary**
- **Overall Technical Approach**
  - Technical Innovativeness
    - Point of Departure Design
    - Feasibility/Substantiation
  - Approach
    - Trade Study and Analysis Plan
    - Risk Management Plan
    - Statement of Work
    - Integrated Master Schedule
- **Military Utility / Concept of Operations**
- **Management**
  - Past Experience
  - Program Team
  - Management Construct/Corporate Capabilities
  - Intellectual Properties
- **Cost**
  - Completeness
  - Substantiations
  - Program Risk (Reasonableness)

BAA Description

BAA Process

Chris Glista for Steven Davis
DARPA/CMO

CMO

BAA PROCESS

ELEMENTS OF THE BAA

- Synopsis in FEDBIZOPPS
- BAA covers all info needed to propose
- TIME PERIOD – BAA is open for **45 days**

ELIGIBILITY

- All interested/qualified sources
- Foreign participants/resources may participate to the extent authorized by applicable Security Regulations, Export Laws, etc.
- Government agencies/labs, FFRDC's, can respond unless otherwise restricted from doing so by law/regulation and/or agency specific policy

CMO

BAA PROCESS

- PROPOSAL PREPARATION/SUBMISSION
  - Instructions are detailed in the BAA (**Follow closely**)
  - **ALL** questions to BAA07-51@DARPA.mil,
  - Q&A and BAA information available on http://www.darpa.mil/tto/solicitations.htm (**Read Regularly**)
  - Funding instruments = primarily contract(s), no assistance instruments (grants, cooperative agreements), OTA for Prototype may be proposed in addition to a contract, but must adhere to OTA guidance http://www.acq.osd.mil/dpap/Docs/policy/otherTransactions/current%20otguideconformed%20Jan%202001.doc
  - Assert rights to **all** technical data & computer software generated, developed, and/or delivered to which the Government will receive less than Unlimited Rights
    - Assertions that apply to Prime and Subs
    - Use defined "Basis of Assertion" and "Rights Category"
    - **Justify** "Basis of Assertion"
    - **This information is assessed during evaluations**

CMO

BAA PROCESS

- Tech Prop - Mind Page Limitations (**don’t use Cost Prop for overflow**)
  - Tech Prop – SOW (by phase, WBS, milestones, deliverables, exit criteria)
  - Cost Prop – Provide **all** Cover Page info
  - Cost Prop – Develop using the same common WBS
  - Cost Prop - FAR Part 15/Table 15-2 (suggested format/content)
  - Provide BOE(s) to support proposed costs (labor & material)
  - Have **all** subcontract proposals ready to submit immediately upon request after BAA closing date

- **Following the proposal instructions assists the evaluation team to clearly understand what is being proposed.**

- **Following the proposal instructions supports a timely negotiation.**

BAA PROCESS

- Be aware of:
  - Organizational Conflict of Interest & Procurement Integrity language
  - CCR, ORCA, & WAWF
  - Export Control language
  - Subcontracting Plan

CMO

BAA PROCESS

- EVALUATION/AWARD
  - Government reserves the right to select for award all, some, or none of the proposals received and to award without discussions
  - Government anticipates making multiple awards
  - No common Statement of Work - Proposals evaluated on individual merit and relevance as it relates to the stated research goals/objectives rather than against each other
  - Only a duly authorized Contracting Officer may obligate the Government

BAA PROCESS

- COMMUNICATIONS
  - Prior to Issuing BAA – No restrictions, however Gov't (PM) shall not dictate solutions or transfer technology
  - After Issuing the BAA – No restrictions, however Gov't (PM/PCO) shall not dictate solutions or transfer technology
  - After Receipt of Proposals – Government (PM/PCO) may communicate with offerors in order to understand the meaning of some aspect of the proposal that is not clear or to obtain confirmation or substantiation of a proposed approach, solution, or cost estimate

Q & A Session

Networking Session
Now – 5 pm