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PROGRESS TOWARD AN EMPIRICAL RELATIONSHIP BETWEEN RELIABILITY INVESTMENTS AND LIFE-CYCLE SUPPORT COSTS

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10th Annual Systems Engineering Conference
October 22-25, 2007
San Diego, CA

Project Phases

- Phase I:
  - Sponsored by DOT&E
  - Using empirical data, investigated the relationships between reliability investment and life cycle support costs.
  - Analyzed the root causes of not meeting R&M requirements.
- Phase II:
  - Co-sponsored by DOT&E and AT&L
  - Building on results from phase I, developing a mathematical model that can be used to predict the investment in reliability required to achieve a given amount of reliability improvement/growth.

Study Approach

- Two overarching constructs
  - Achieved reliability = f (goal setting, technology, reliability effort)
  - Support cost = f (usage, product design, support process design)
- Gap analysis between the earliest and the most recent data available
- Statistical analysis of reliability investment and reliability improvement

Limitations

- Data availability and quality. Problems with incomplete, corrupted, and missing data were pervasive.
- Small sample size--empirical data limited to six case studies.
- LCCs were estimated by CASA model--not actuals.
- Assumed reliability investments were the cause for observed reliability improvements.
- When LRU-level costs were not available, subsystem level costs were allocated to the LRU level.

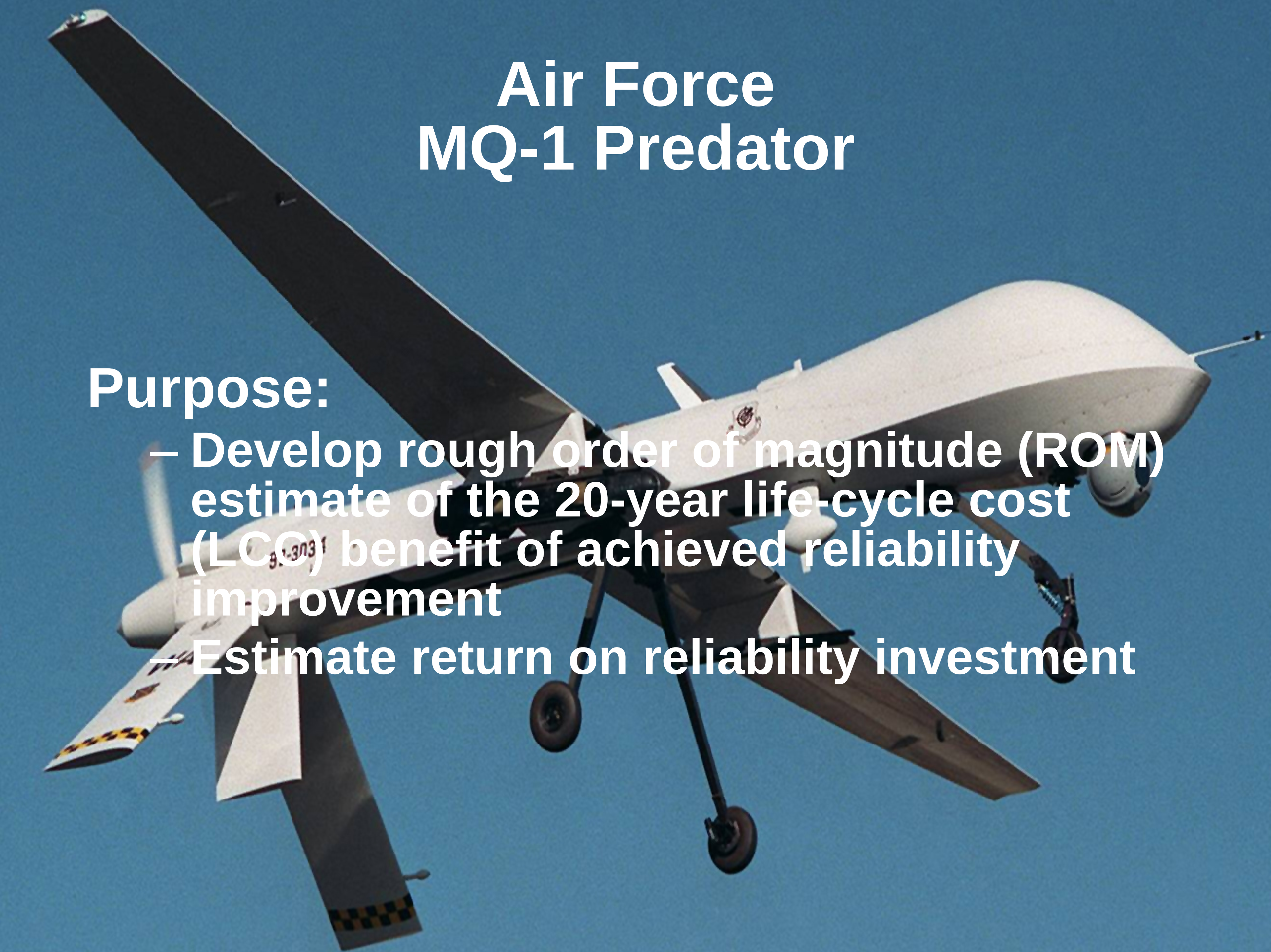
CASA = Cost Analysis Strategy Assessment Model

Bottom Line Up Front

- Reliability goals did not appear to be driving either management or engineering effort.
- Availability and use of mature technology was not an issue.
- Programs significantly improved system reliability.
  - Improvement ranged from 50% to 674.5%
  - Improvements were partially the result of enhancements to resolve performance limitations.
  - In four of five cases, programs made a deliberate effort to improve reliability in its own right—2 of 4 cases after OT or IOC.
- Programs significantly reduced life-cycle support costs.
  - Percent reductions ranged from 23% to 86%.
  - However, under investment in reliability may be large (discussed later).

Case Studies

- Predator
- Global Hawk
- CH-47F (characterized improvement but did not model LCC)
- MH-60S
- FBCB2
- Complex Ground Vehicle Electronics System



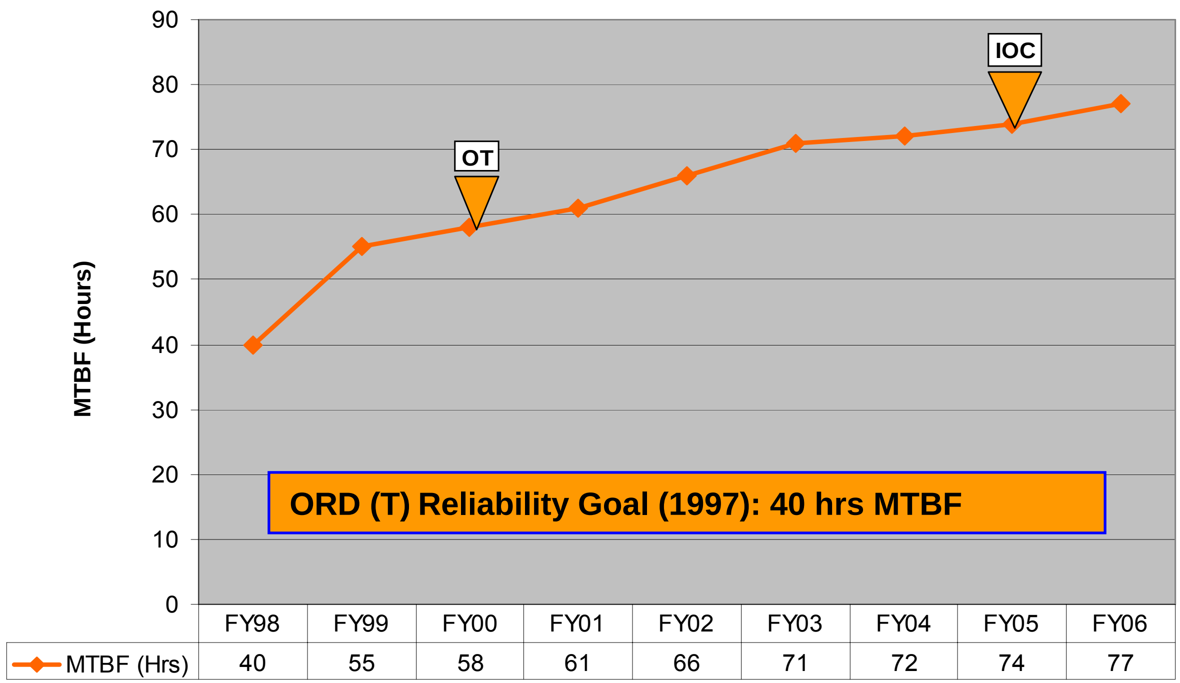
Air Force
MQ-1 Predator

Purpose:

- Develop rough order of magnitude (ROM) estimate of the 20-year life-cycle cost (LCC) benefit of achieved reliability improvement
- Estimate return on reliability investment

Predator Analysis

Reliability History



Reliability Investment and Support Cost Reduction								
Case Study	MTBx Hours			CASA 20-Year Support Cost (costs in FY03 M $, discounted 7%			Economics (FY03 M $)	
	Was	Is	Percent Change	Was	Is	Percent Change	Reliability Investment	ROI
Predator	40	77	92.5%	$1,463,940	$576,663	60.6%	$39.1	22.7:1

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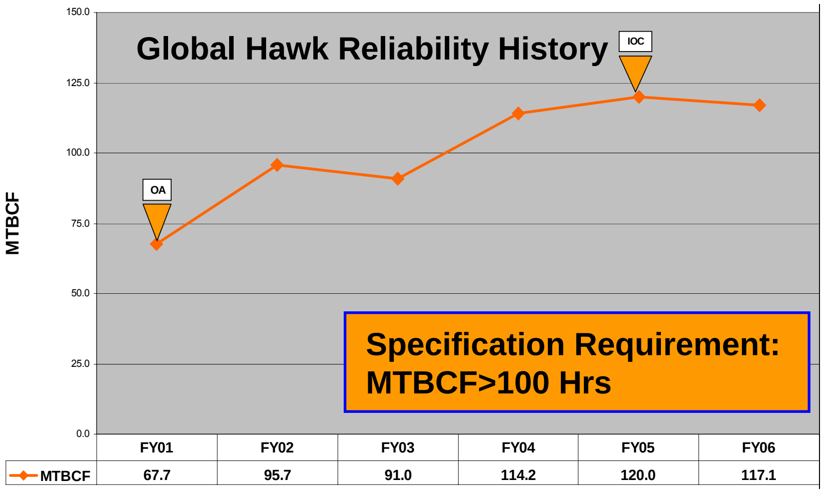
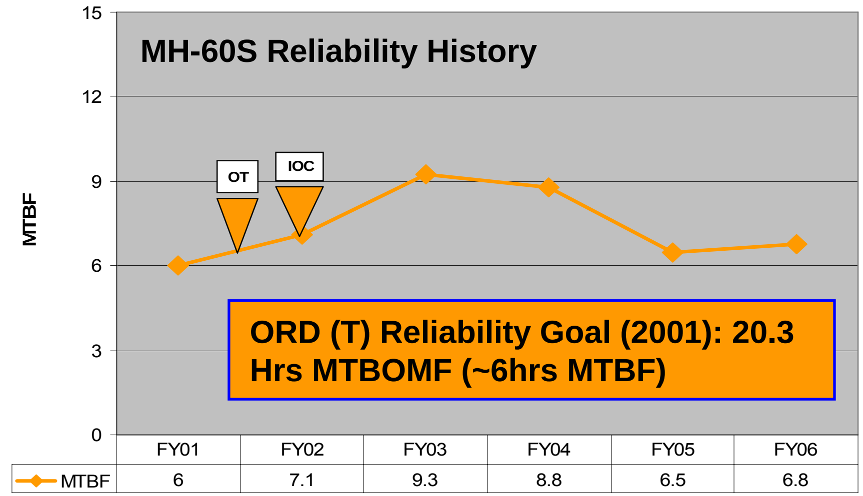
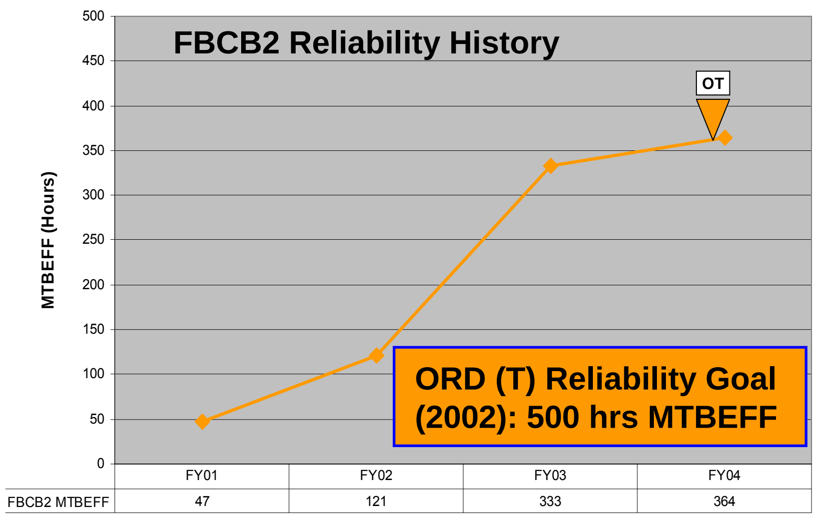
Global Hawk, MH-60, and FBCB2







Reliability Investment and Support Cost Reduction

Case Study	MTBx Hours			CASA 20-Year Support Cost (costs in FY03 M $, discounted 7%			Economics (FY03 M $)	
	Was	Is	Percent Change	Was	Is	Percent Change	Reliability Investment	ROI
Global Hawk	67.7	120	77.3%	$2,547,380	$1,958,759	23.1%	$121.9	5:1
*MH-60	2.4	3.6	* 50%	$384,602	$64,672	83.2%	$6.6	49:1
FBCB2	47	364	674.5%	$13,060,351	$1,880,763	85.6%	$87.4	128:1

* Improvement over HH-60 for like components

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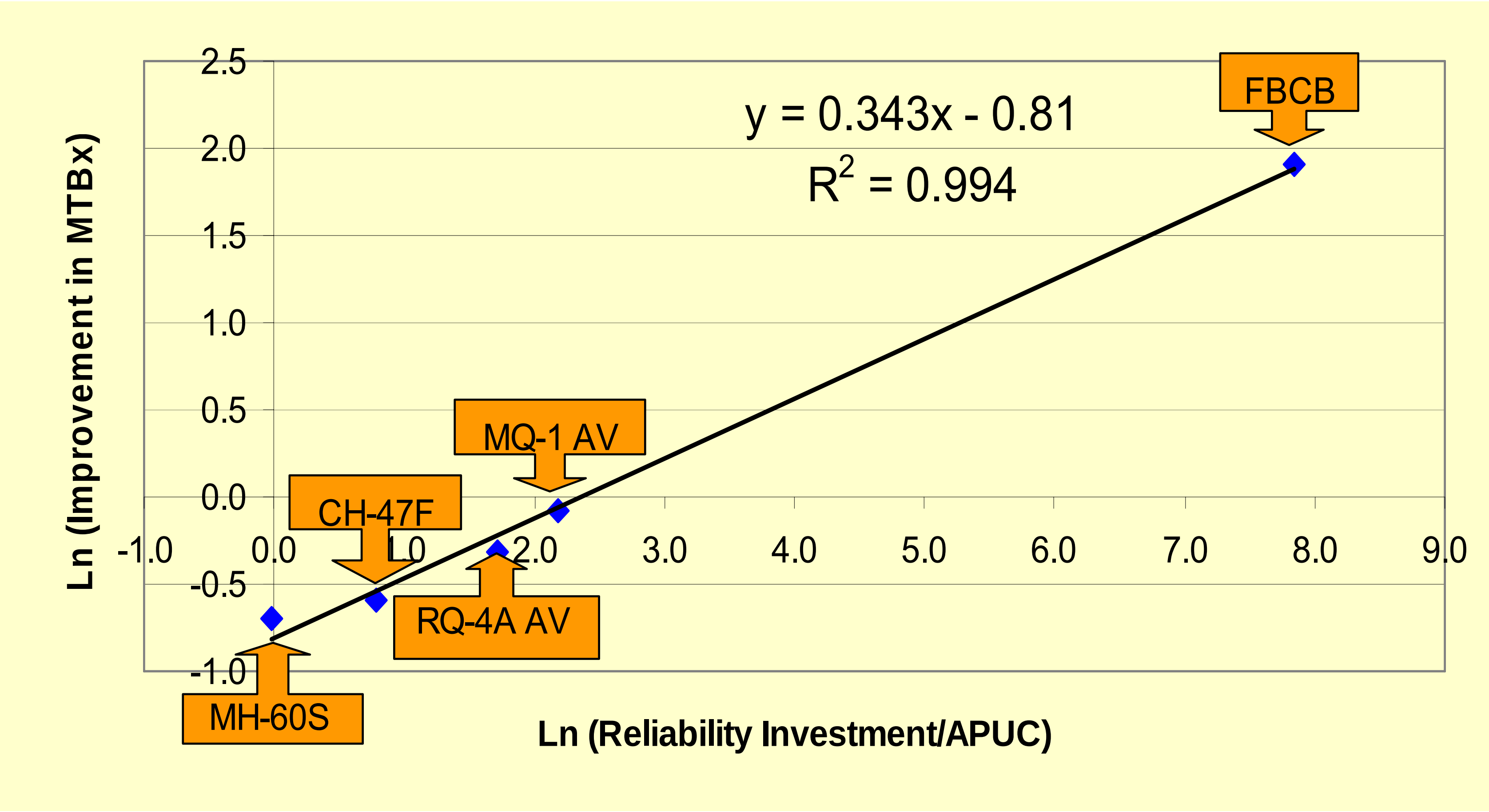
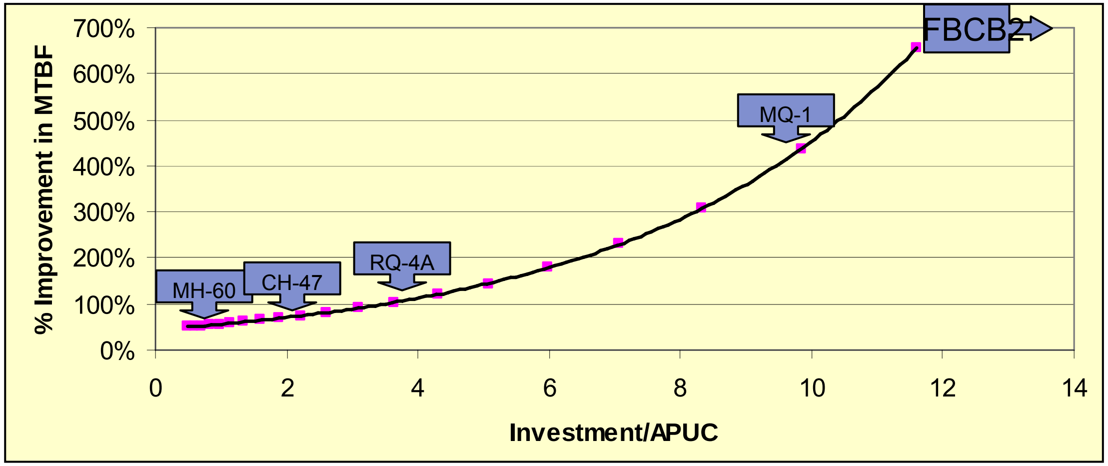
Reliability Improvement vs. Investment Phase I

(Excluding Complex Ground Vehicle Electronics System)



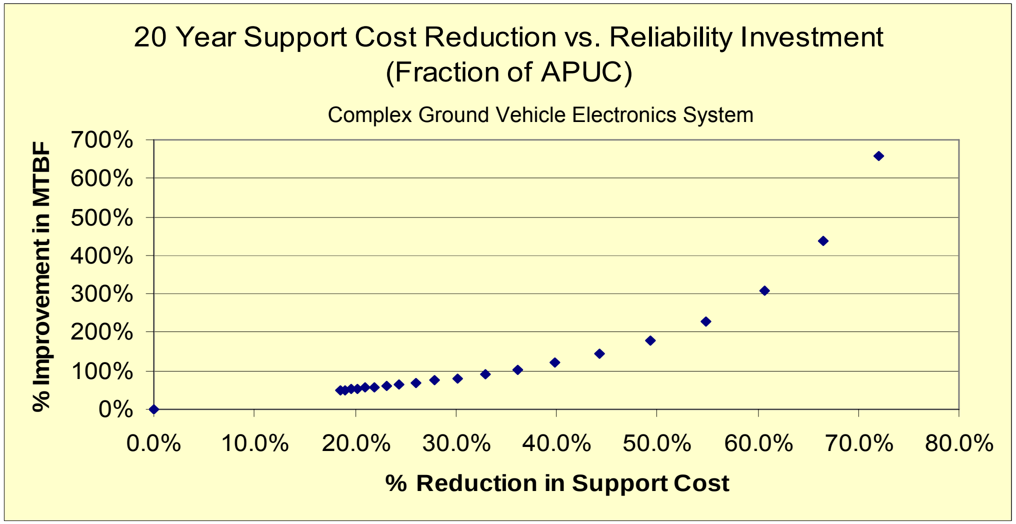
Translating Reliability Investment Into Support Cost Reduction (Complex Ground Vehicle Electronic System Example)

Phase I



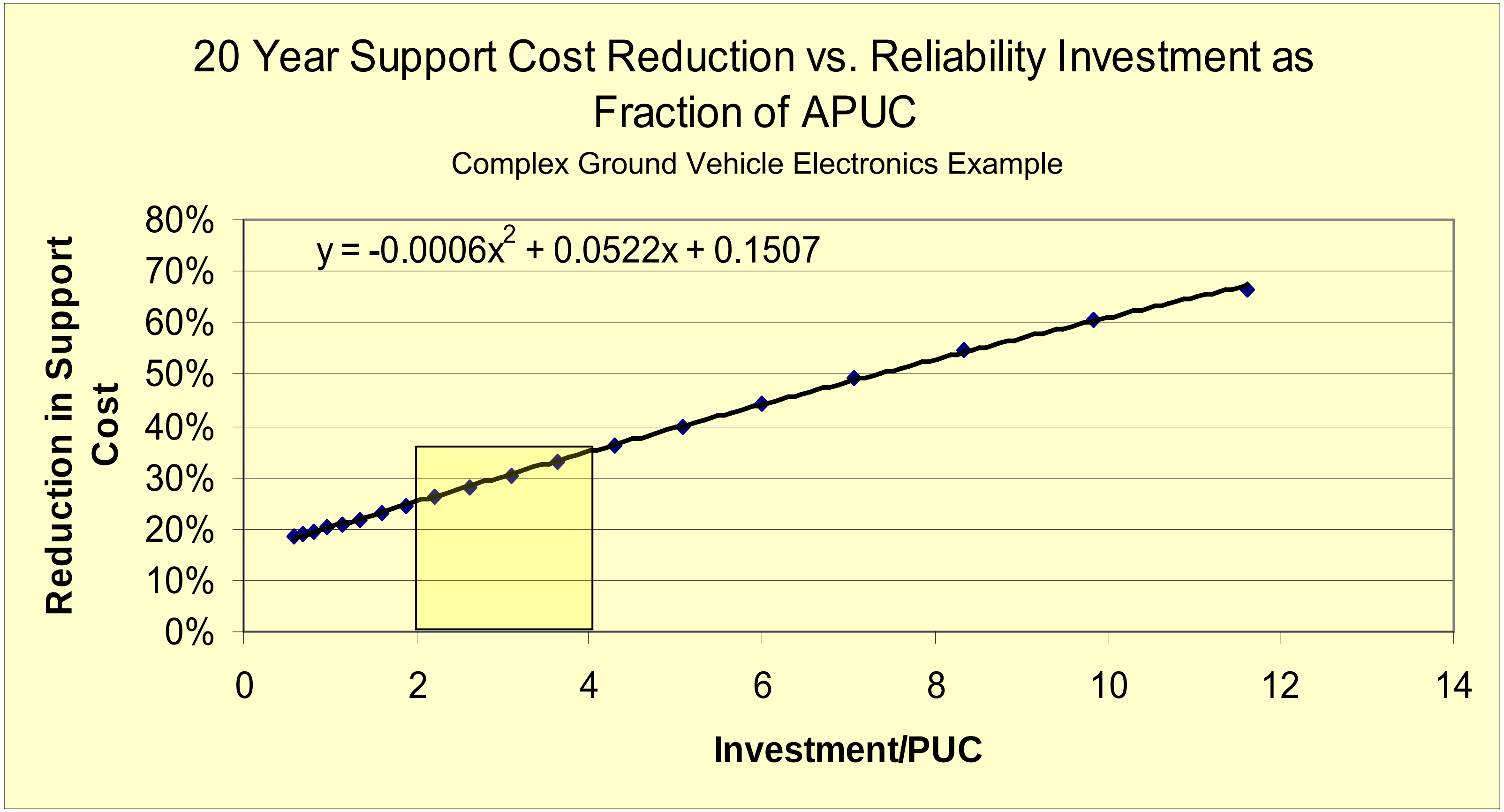
Potentially technology and application neutral

Most likely technology and application dependent



Translating Investment as Fraction of APUC Into Support Cost Reduction

Phase I



Preliminary Results

Conclusions

- Achieving Reliability
  - Goals
    - All five case studies for fielded systems had established goals
    - …but did not manage to requirements
  - Mature technology: available and incorporated
  - Effort
    - With possible exception of FBCB2, reliability effort was not evident during design
    - Two cases with reliability effort did it after OT/IOC
- Reliability and ROI
  - Clear evidence that reliability investment reduces support cost
    - ROIs of 5:1 to 128:1 on reliability improvement effort
    - 30% to 80% (or more) reduction in support cost achievable
  - Reacting to unreliability after OT/IOC rather than preventing it up-front is probably leaving significant support cost reduction unrealized

Project Phases

- Phase I:
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- Phase II:
  - Building on results from phase I, develop a mathematical model that can be used to predict the investment in reliability required to achieve a given amount of reliability improvement/growth.

Model Comprises Four Sub-models

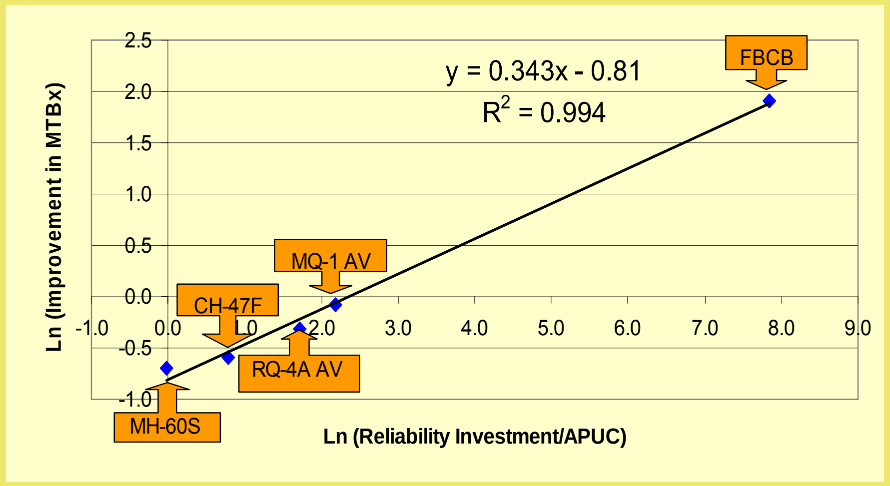
1. A basic model that computes reliability development effort and cost as a function of program size and desired reliability improvement
2. An intermediate model that computes development effort as function of program size, desired reliability improvement, and a set of relevant cost drivers
3. A detailed model that incorporates the characteristics of the intermediate version with an assessment of the cost driver's impact on each step (analysis, design, etc.) of the reliability engineering process
4. A companion production/support cost model to estimate
   – delta investment in production (e.g., for retrofit and spare parts) and
   – change in operations and support cost.

Study Plan

- Phase IIa (DOT&E-funded)
  - Basic model
    - Extension of work done under cost of unreliability task
    - Robust the underlying set of data from 8 programs and projects to about 16
    - Provide cost estimating relationship usable by program managers, including
      - Applicability
      - Statistical properties
      - Limitations
  - Target completion February 2008
- Phase IIb (AT&L-funded)
  - Intermediate model
  - Companion production/support cost model
  - Target completion June 2008
- Potential follow-on
  - Detailed model…if warranted by results of phase II

Phase IIa Approach: Focus on Investment to Reliability Relationship

- Extend cost of unreliability study, analyze in-service programs
  - Reliability improvement
  - Cost to achieve the improvement
- Key elements
  - Emphasize homogeneity of data
    - Same cost content across programs
    - Consistent reliability counting rules within a program
  - Look for disconfirming evidence: programs that do not appear to follow the log-log relationship between normalized investment and improvement, reasons why



Relationship	Source of data/Comments
Investment to reliability improvement	Across air, sea, ground domains; confirm domain independence
Reliability improvement to cost of ownership reduction	Single domain (air?); characterize within domain behavior Gather data in phase I, limited analysis

Cost Content

- Funds identified for reliability improvement
- Funds budgeted for test related to reliability improvement
- Related systems engineering funds

Summary

- Phase I
  - Using empirical data, investigated the relationships between reliability investment and life cycle support costs.
  - Analyzed the root causes of not meeting R&M requirements
- Phase II
  - Extending work from phase I
  - Developing a cost estimating relationship usable by program managers, including
    - Applicability
    - Statistical properties
    - Limitations

Additional Slides

Phase I

Reliability Overview by Case Study

Dimensions	Reliability Goal ORD (T)	Technology Readiness	Management Effort	Fail Rate Reduction
Cases				
Predator (Air Vehicle)	40 hrs MTBF	• Advanced Concept Technology Demonstration (ACTD) system acquisition. • After initial fielding, ACTD platform upgraded with better performing and more reliable Engine, Communications, Flight controls, and Sensor Payloads.	•As evidenced in budget justifications, concerted emphasis was placed on improving overall system reliability as part of improving performance.	48.1%
Global Hawk (Air Vehicle)	Effective Time on Station (ETOS) > 85%; MC>85%; Translate to MTBCF>100 Hrs (Spec)	• Advanced Concept Technology Demonstration (ACTD) system acquisition. • After initial fielding, ACTD platform upgraded in Block 10 spiral with better performing and more reliable Electrical Power, Communication (Data Link) Improvements, Flight controls, and Sensor Management Unit (SMU) configuration.	•PM/OEM data and budget justifications indicate numerous trade studies and other engineering initiatives to improve performance and reliability.	43.6%
Ch-47F	The original goal 44 hrs MTBMA was changed in 2006 to 30 hrs MTBMA	• Remanufacture of CH-47D to Ch-47F airframes and new zero time CH-47F aircraft • New Platform Airframe to reduce vibration, Common Avionics Architecture System to improve avionics, upgraded 714B Engine with enhanced lift capability and reliability, Engine Air Particle Separator to improve engine reliability, and reliable Electrical Power Supply and Distribution system	• PM Improved Cargo Helicopter (ICH) contracted with Avion, INC in 2002 to baseline and manage RAM data collection and analyses. • Failure Modes Effects Analysis (FEMA) currently being used to identify reliability bad actors, although not used to drive initial design.	35.8%
MH-60S	20.3 hrs MTBOMF (~6hrs MTBF)	• Remanufacture of HH-60 H aircraft • Investments in CPU, PWR SYS, DRIVE SHAFT ASSY, NAV COMPUTER, STABILATOR AMPLIFIER, BEAM-AXLE AASY, FLOOR ASSY, and IR TRANSMITTER improvements have improved aircraft performance and supportability. • Overall aircraft reliability has shown moderate reliability gains due to unreliability of older subsystems.	• Did not find specific budget justifcation for reliability improvement • NAVAIR PMA-299 is working with the Army and other Navy programs to share investment expenses to improve reliability of bad actors such as retaining bolts, gaskets, and bearings.	33.3%
FBCB2	500 hrs MTBEFF	• Beginning with tests and reliability demos on competition systems, investments in components ruggedized for operating environments, improved power supply, redesign of internal components to dissipate heat and removable hard drives and dust filters were made to improve LRU reliability and overall system performance.	• Using data from reliability demonstrations, field tests and operational tests and analyses to drive reliability improvement. • As evidenced in budget justifications, investments are being made in hardware and software reliability improvements.	87.1%

Data Availability by Platform/System

Platform	Usage Data Density, OPTEMPO		Product Data Failure rate, MTBF, MTTR, MR	Support Process Data CWT, Cycle Times, NRTs
MQ-1 Predator	Gaps in flying hours data in AFTOC. Useable data provided by MAJCOM.		Usable data available from OSD Studies, PM, and other sources	Limited visibility into contractor support processes. Used default values.
RQ-4A Global Hawk	Gaps in data. Flying hour counting rules vary by operational unit. (Beale reports pre and post flight operations in FH data; Edwards does not.)		Reliability data parameter measured in the field (MTBF) not consistent with the parameters used to establish ORD requirement (ETOS>100 hrs)	Limited visibility into contractor support processes. Used default values.
FBCB2 Appliques	OT	Other than for OT, unable to locate usage data. Does not appear to be captured.	Used DT/OT data available from AEC and IDA. Data differs by source for same test events.	Limited visibility into contractor support processes. Used default values.
MH-60S	Usable data available from PMA 299		Reliability data parameter measured in the field (MTBF) not consistent with the parameters used to establish ORD requirement (MTBOMF)	Usable data available from PMA 299
Stryker	FY 2002 to FY 2005 CLS data unavailable. CLS Data for FY 2005.5 to FY 2006.5 for two Stryker brigades.		Limited data available, pedigree suspect or unknown	Limited visibility into contractor support processes. Because of other missing data did not model.
CH-47F	OT data available for 5 aircraft: 2-EMD Aircraft 2-zero time CH-47F Aircraft 1-Hybrid Aircraft, CH-47D outfitted with a CAAS cockpit		Reliability data parameter measured in the field (MTBF) and ORD requirement (MTBMA) are used interchangeably. Unclear whether data contain all failures or only those causing mission abort.	Data appear to be unavailable

Usable data available from standard source
Usable data available from PM or other sources
Data problematic: incomplete, inconsistent, pedigree suspect or unknown
Data appear to not be available