Effective Implementation of Systems Engineering at the Aeronautical Systems Center:
A Systems Engineering Tool Set

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ASC/ENS

Outline

Rapidly delivering war-winning capability

- Background
- ASC/EN Perspective
- Policy and Approach
- Applied SE tools (for Airplanes)
- Summary

ASC/EN oral discussion is required part of this presentation.

Recent SE Guidance

Policy:

- OSD Memo, 22 Oct 2004, ***Policy Addendum for Systems Engineering***
- OSD Memo, 20 Feb 2004, ***Policy for Systems Engineering in DoD***
- SAF/AQ Policy Memo, 7 Jan 2004, ***Revitalizing Air Force and Industry Systems Engineering***
- SAF/AQ Policy Memo, 9 April 2003, ***Incentivizing Contractors for Better Systems Engineering***
- SAF/US and SAF/AQ Policy Memo, 20 Sep 2004, ***Revitalizing the Software Aspects of Systems Engineering***
- ASC/CC Memo, 4 Oct 04, ***PEO Policy for Systems Engineering***

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ASC/EN Perspective

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- Critical aspect of Systems Engineering effectiveness: program implementation
  - Need good practices at the working level
  - Meaningful SE content in contracts is important
- Significant challenge: Systems Engineering within a performance-based environment
- SE practitioners need tools to help them work
  - Standards & references
  - Guidance documents
  - Training
  - Shortcuts

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Our challenge

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What Have

YOU

Done Today That's

Relevant to Engineers in the Program Offices ?

<u>Practical solutions</u> to systems engineering issues …

…within the context of <u>performance-based acquisition</u>

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Performance-based Acquisition:
Responding to Paradigm Change

- 1994 Sec Def Policy changed environment
  - Performance not prescription – reduced Mil Stds (esp process)
  - Focus on flexibility/efficiency/streamlining/innovation
- Resultant action: Significant and critical SE shift
  - Emphasis on contract specification: functional and interface requirements and <u>verification</u>
    - Adjusted for what was embedded in Mil Stds
  - Processes: Measure results (of contractor processes) vice dictating process
    - Information focus: evidence of product maturity for planned activity

New Thinking, New Tools, New Approach

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New SE Application Paradigm

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- Acquisition reform initiatives
  - Did <u>not</u> eliminate disciplined systems engineering!
  - Performance requirements at the appropriate level of detail
  - Evidence of sound, disciplined systems engineering
- Tools contain essential program content
  - Information focused; not “how to” or process control
- Provide tools to contractor
  - RFP language
- Contractor tailors content for program
  - **Embed in contract** (SOW, Spec, WBS, IMP)
  - Establishes common understanding of program content (avoid ECP’s later)
- Government assesses progress & results
  - Process outputs & information products

Contract Framework

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Government Requirements

(Architecture, CDD, RFP L&M, SRD, etc)

Contractor's Processes

Facility Processes (Generic)

Contractor's Concept

Program Specific Plan

Sec Def Perry Reform 1994
"Performance Based Acquisition"
frames today's acquisition

What does the SE content include?

Actual Program

System Specification*
- Performance and verification basis

Allocated requirements

IMP* – What
- Incremental (entrance/exit criteria)
- Insight/measure product acceptance at each supplier level

IMS – When

SOW* and WBS – Work content

Selective Mil Stds*, Specs, Hdbks

Budgets, Schedules, Staffing

Process Metrics*
- Cost
- Performance
- Schedule
- Quality

* Contractual commitment with Gov't

ASC PEO Policy

Signed by ASC/CC 4 Oct 04

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- Commanders/Directors/Senior Functionals implement SE Policies (OSD & AF)
- ASC/EN responsible for SE tools and guidance for ASC programs (work with ACE)
- New SDD/major modifications
  - Develop SEPs – SE tool foundation
  - Product integrity and AW Plan in contract (IMP, etc)
  - Independent first flight/AW assessment required
- Existing programs employ SE tools for reviews, incentives, and health assessment

Why Policy? By-product of reorganization to Wings/Groups/Squadrons and emphasis on focusing/maintaining Center's critical practices

ASC/EN would discuss as required during presentation.

SE Emphasis

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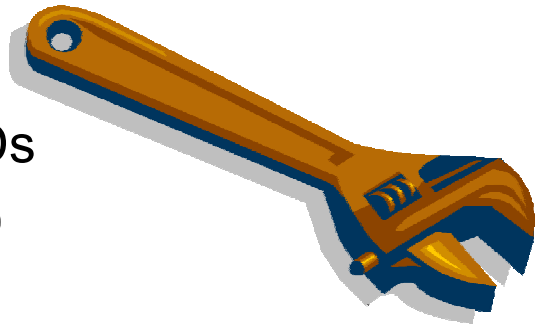
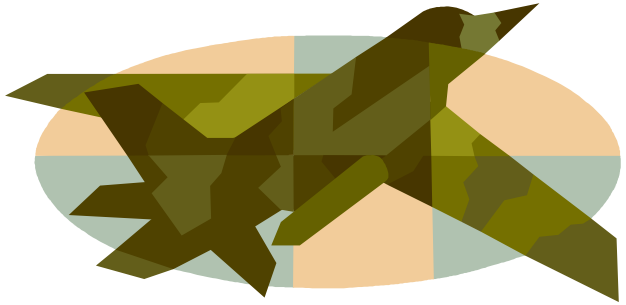
- ASC Policy foundation: SE content in program contract/execution
  - "SE Tool Set" -- RFP language, guides, MIL STDs
  - Linkage to SOW, IMP, WBS (all levels of supply)
  - Information focused – not "how to" or process
    - Event based review structure
    - Tailorable criteria – verification emphasis
    - Health assessment/metrics
  - Improved program cost estimating
  - Drive life cycle planning
  - Applies to new and existing programs
- Basis for SE Plans





Tools accessible via ASC/EN Web site

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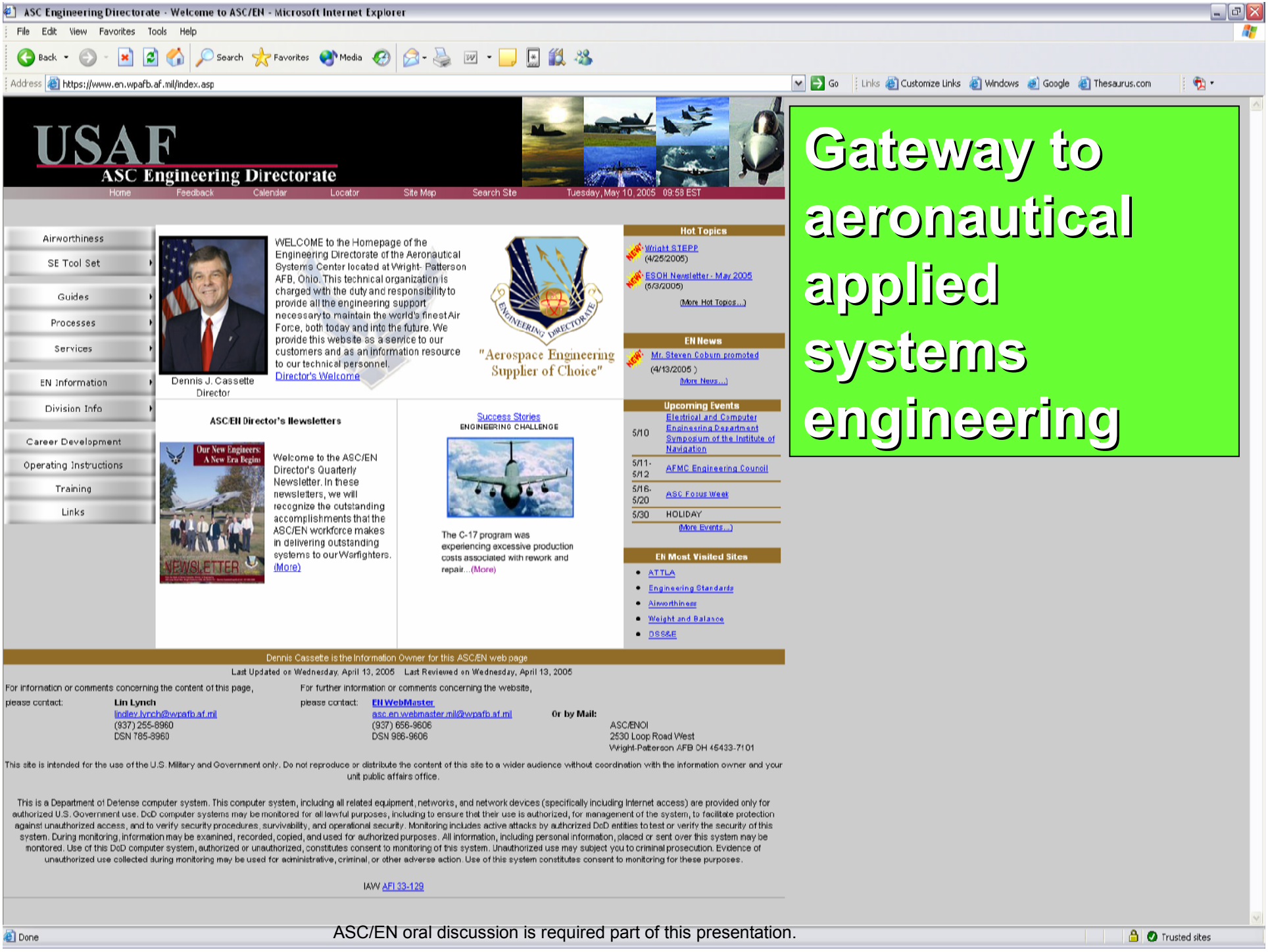

Gateway to aeronautical applied systems engineering

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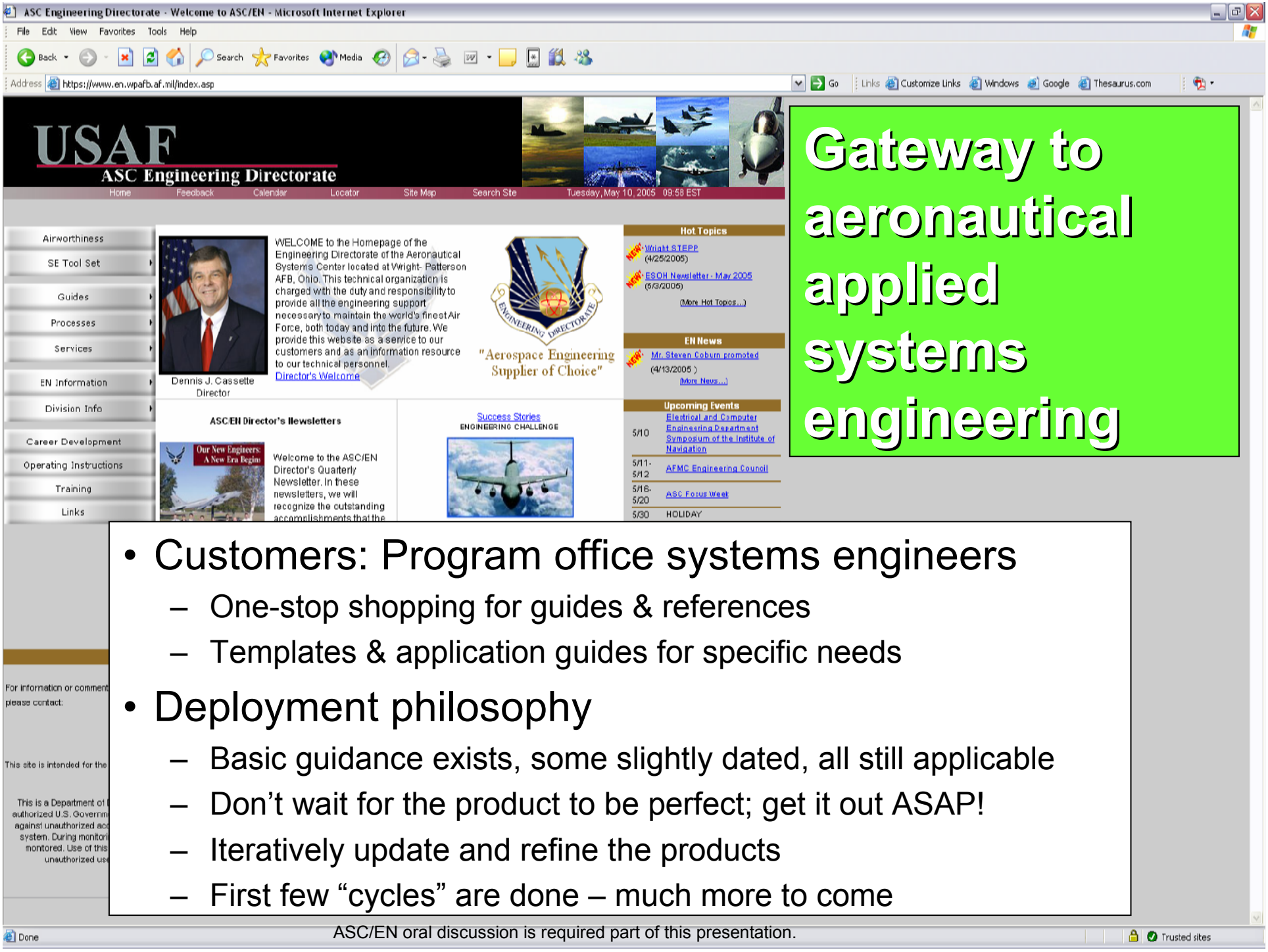

Gateway to aeronautical applied systems engineering

- Customers: Program office systems engineers
  - One-stop shopping for guides & references
  - Templates & application guides for specific needs
- Deployment philosophy
  - Basic guidance exists, some slightly dated, all still applicable
  - Don’t wait for the product to be perfect; get it out ASAP!
  - Iteratively update and refine the products
  - First few “cycles” are done – much more to come

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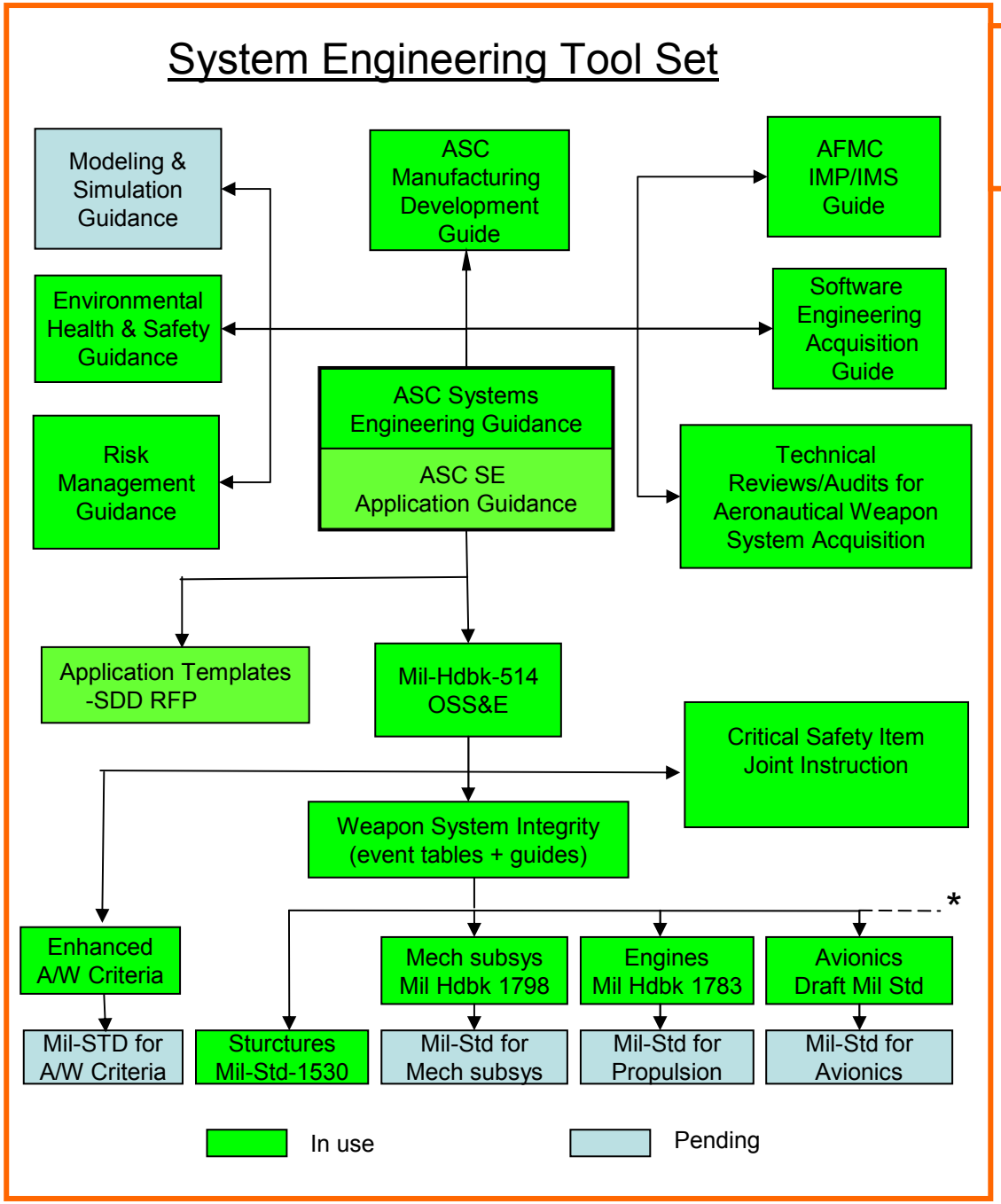
System Engineering Tool Set



Use SE Tool Set to Derive Program Specific Applications

Core SE Foundation

Program Unique Products

- Acquisition Strategy
- Systems Engr Plans
- Development Contract(s)
  - SOW
  - SPEC
  - IMP/IMS
- Production Contract(s)
- Sustainment Activities

https://www.en.wpafb.af.mil/

* Working Integrity criteria and standards for crew systems and vehicle management

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Tool Set

U.S. AIR FORCE

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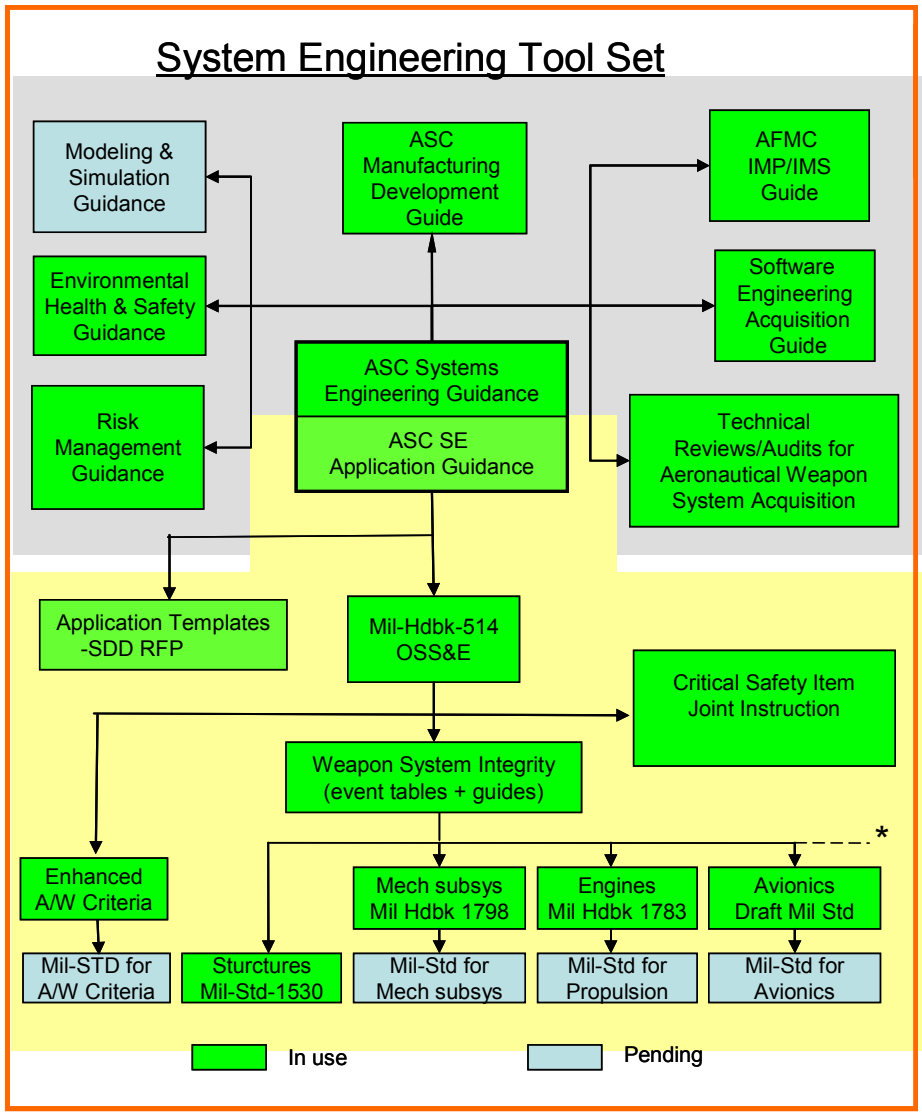

Universal SE Guidance

- Single source for reference documents
- Guides for key processes
- Generic information – application beyond aeronautical systems
- "Basic training" material

Aircraft-specific Guidance

- ASC/EN corporate knowledge & lessons learned
- Emphasis on event-based format
- Minimal essential contract content
- Detailed handbooks available for reference

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Example: ASC SE Guide

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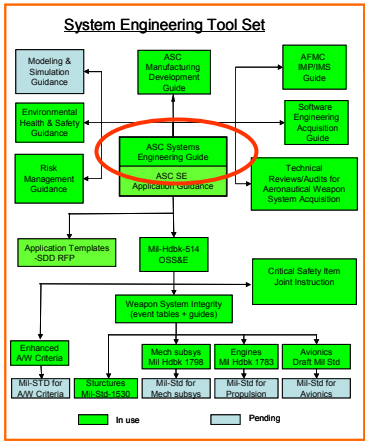
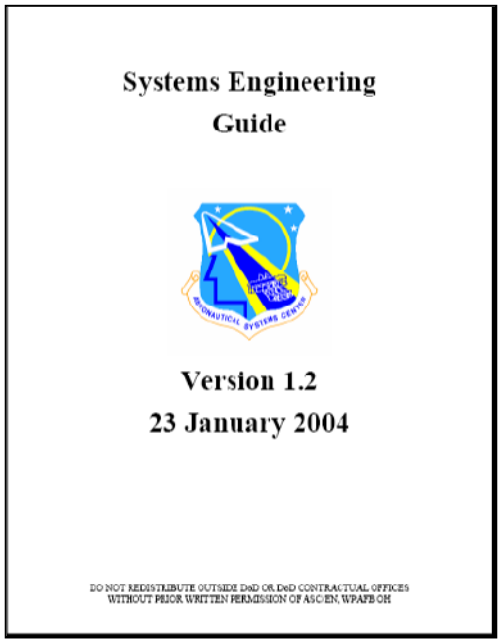


- "Classical" systems engineering content
  - Minor update to unpublished draft of Mil-Std-499B
  - Consistent with current DoDI 5000 series

- Defines the "what" of SE
  - Overall concept and sub processes (e.g. requirements definition & allocation, incremental verification, etc)
  - Not a "how to do" document
- Useful background to establish context for SE application tools
  - Understand the big picture
  - "Pointers" to the rest of the toolset


Systems Engineering Guide

Version 1.2

23 January 2004

DO NOT REDISTRIBUTE OUTSIDE DoD OR DoD CONTRACTUAL OFFICES WITHOUT PRIOR WRITTEN PERMISSION OF ASC/EN, WPAFB OH

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Example: SE Application Guide

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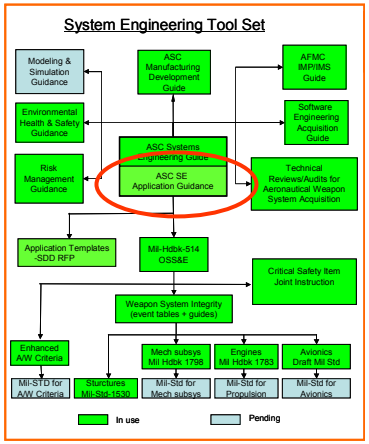
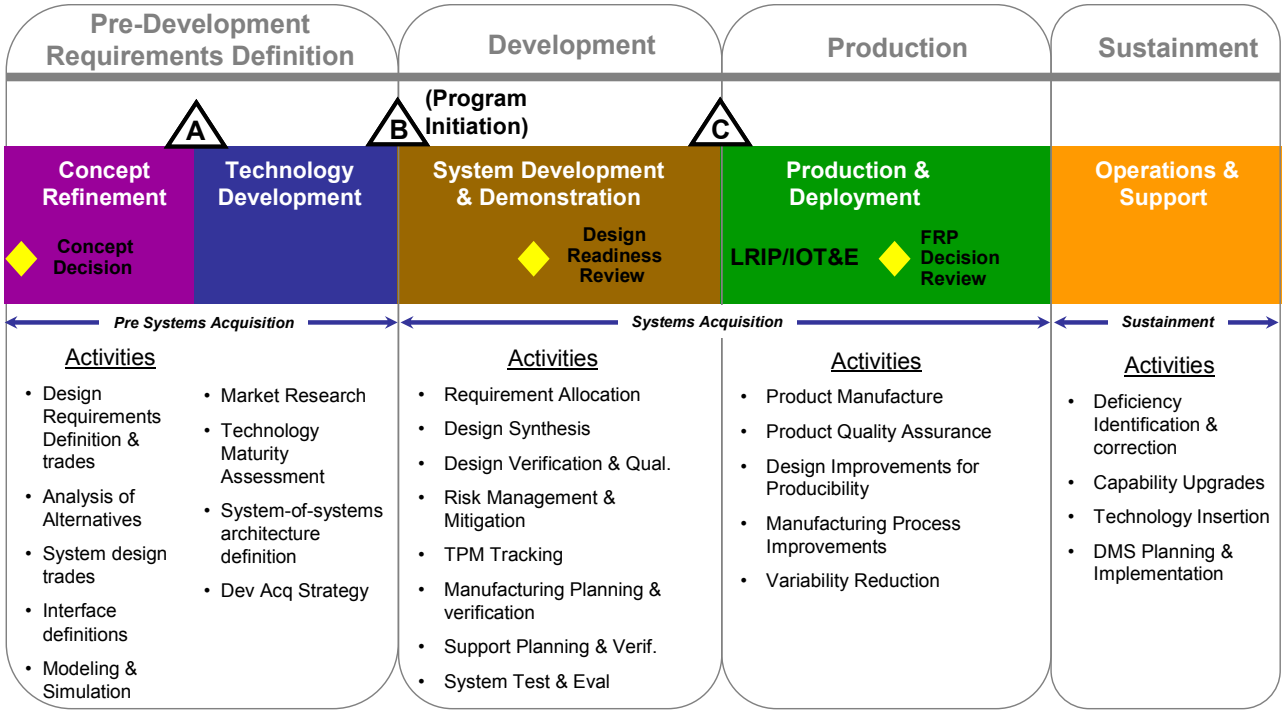


- Event-based guide – performance-based approach
- Focus on key information from SE process that describes technical maturation of the system



Under Construction

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SE Application Guide
Information for Technical Maturation

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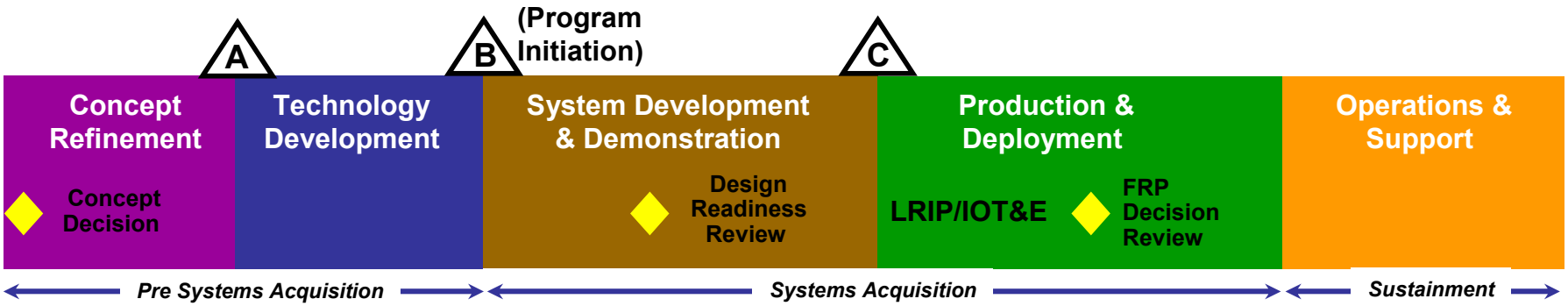

TECHNICAL MATURATION:
Evolution from general concepts to validated, producible products

- **The systems engineering process guides maturation of the system**
- **Product definition moves from low to high fidelity – iterative "loops" of design-verification activities**
- **Baselines & technical reviews are used as anchor points**
- **Increasing understanding of system behaviors (M&S, test)**
- **Risk moves from high to low as experience increases**

SE Application Guide identifies information products that describe key aspects of technical maturation

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Aeronautical Program SE Content
90% Solution

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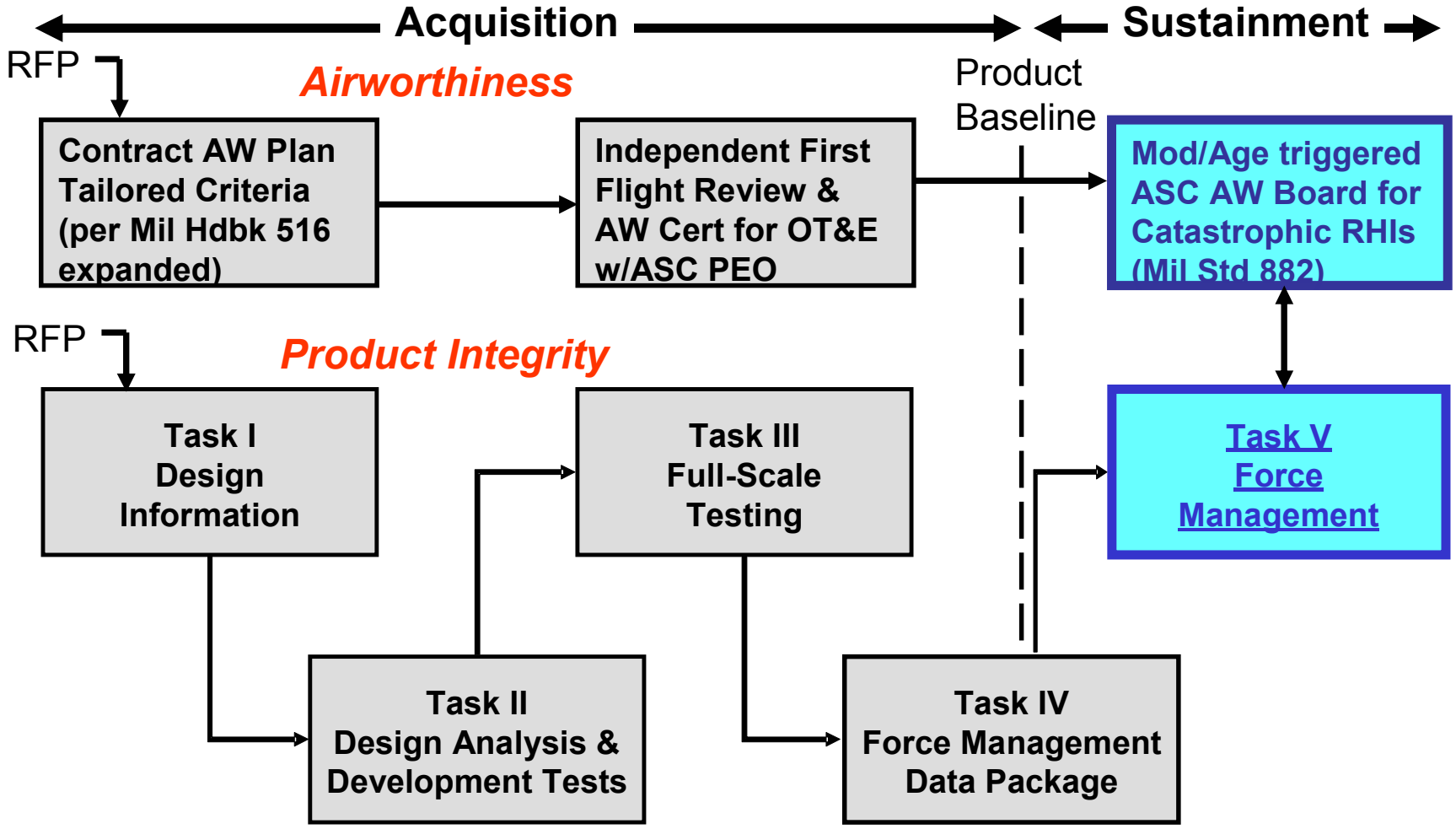

Frames the program's SE effort & Technical Baseline

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Airworthiness

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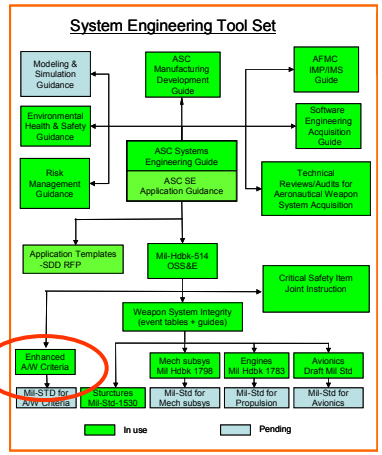
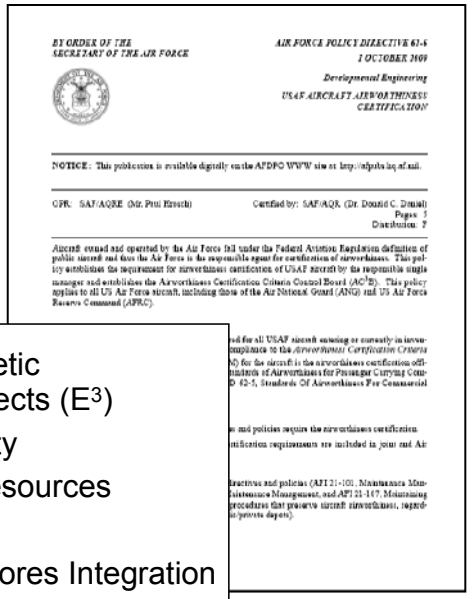
Airworthiness certification – Repeatable process resulting in a decision by a Single Manager that pilots and maintainers can safely operate and maintain an aircraft within its documented operational and maintenance limits.




BY ORDER OF THE SECRETARY OF THE AIR FORCE

AIR FORCE POLICY DIRECTIVE 61-6
1 OCTOBER 1999

Developmental Engineering

USAF AIRCRAFT AIRWORTHINESS CERTIFICATION

NOTICE: This publication is available digitally on the AFDPO WWW site at http://afpubs.hq.af.mil.

OPR: SAF/AQRE (Mr. Phil Hirsch)

Certified by: SAF/AQX (Dr. Donald C. Daniel)

Pages: 7

Distribution: F

Aircraft owned and operated by the Air Force fall under the Federal Aviation Regulation definition of public aircraft and thus the Air Force is the responsible agent for certification of airworthiness. This policy establishes the requirement for airworthiness certification of USAF aircraft by the responsible single manager and establishes the Airworthiness Certification Criteria Control Board (AC³B). This policy applies to all US Air Force aircraft, including those of the Air National Guard (ANG) and US Air Force Reserve Command (AFRC).

- 1.0 Scope
- 2.0 Applicable Documents
- 3.0 Definitions and Abbreviations
- 4.0 Systems Engineering
- 5.0 Structures
- 6.0 Flight Technology
- 7.0 Propulsion and propulsion installations
- 8.0 Air Vehicle Subsystems
- 9.0 Crew Systems
- 10.0 Diagnostic Systems
- 11.0 Avionics
- 12.0 Electrical System
- 13.0 Electromagnetic Environmental Effects (E^3)
- 14.0 System Safety
- 15.0 Computer Resources
- 16.0 Maintenance
- 17.0 Armament/Stores Integration
- 18.0 Passenger Safety
- 19.0 Materials
- 20.0 Other Considerations
- 21.0 Notes
- A.1 Scope
- A.2 Technical Points of Contact
- A.3 Cross-reference -516A to -516B

Expanded MIL-HDBK-516 contains over 350 pages of technical criteria for manned, unmanned, and fixed or rotary wing air vehicle development

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Tool Set Example
Structures Airworthiness Criteria

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Entrance

5.1.3 *Verify that the **limit loads** used in the design of elements of the airframe subject to deterministic design criteria are the **maximum and most critical combination** of loads that can result from authorized **ground and flight use** of the air vehicle. These include **loads during maintenance activity, system failures** from which recovery is expected, and loads experienced throughout the **specific lifetime usage**.*

Standard*: Airframe is designed such that all loads whose frequency of occurrence is greater than or equal to **1 x 10-7 per flight** are used. Airframe is designed such that analytical loads are **correlated** against **measured ground and flight test loads.**

Compliance*: Correlated **ground and flight loads analyses** in which details of magnitudes and distribution of all applied external loads are identified for **multiple** air vehicle **configurations**, **weights, c.g. and maneuvers** covering all attainable **altitudes, speeds and load factors**. Establishment of the **service and maximum loads** expected to be encountered during operation under **all flight conditions**. **Wind tunnel tests** utilized for development of aerodynamic loads. **Stiffness** and **ground vibration tests** utilized to **update** flexibility vs rigid characteristics of loads **analytical model**. Flight controls and aerodynamic flight tests utilized to update aircraft **simulation models**. **Loads calibration tests** utilized to develop ground/flight load equations. 80% and 100% flight loads surveys/demonstrations utilized to correlate analytical model and to substantiate the design loads.

Exit

DoD/MIL Doc: JSSG-2006: A3.2.11, A4.2.11.

*Tailorable – Draft AWP with proposal, updated prior to PDR; AW baseline is declared final at PEO determination of readiness for dedicated OT&E

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Integrity Process

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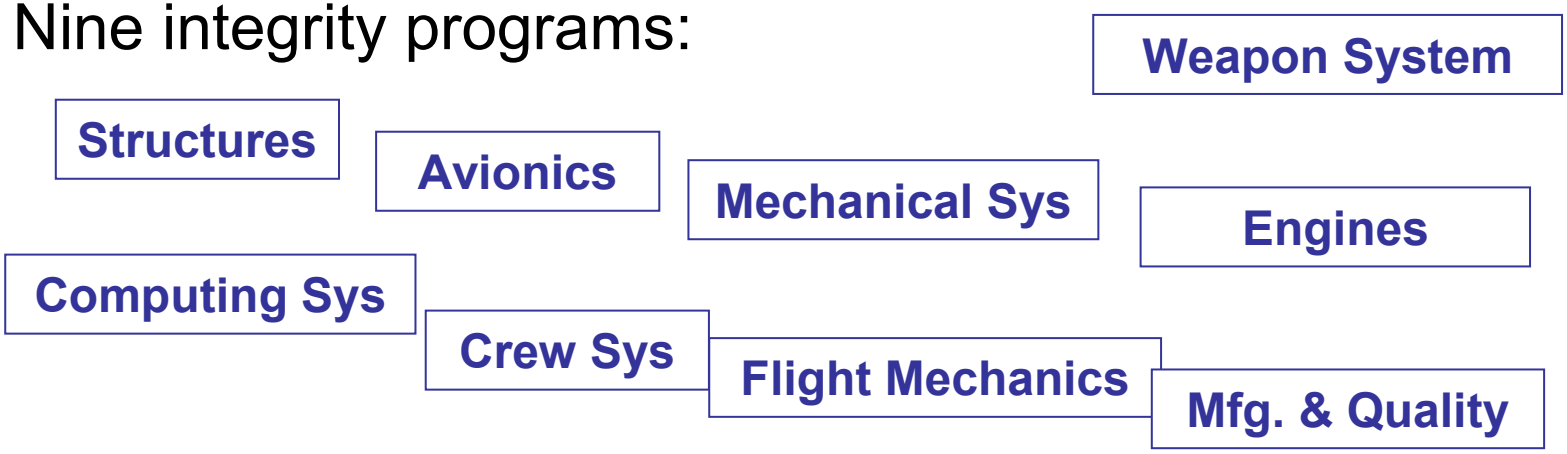
- Disciplined technical process for a weapon system
  - Ensures that it will meet Operational Safety, Suitability, and Effectiveness (OSS&E) directives
  - Applies to entire operating envelop & environment
  - Cradle to grave: addresses entire life cycle

- Nine integrity programs:



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Example: Integrity Table

Engine Integrity Program

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Preliminary Design Review	Critical Design Review				Functional	
II - Design Analysis, Materials Characteristics & Development Tests		**III - Component & Core Tests**				
ENSIP Master Plan Update	ENSIP Master Plan Update	**Component Tests:**	Core Engine T	Data Acquistion &	**Ground Tests:**	
Duty Cycle	Materials Characterization	Strength	F			
Design Development Tests	Detailed Analyses:	Vibration	Aeron			
Preliminary Analysis:	Durability	Durability	Thermals	Test Plan	Damage Tolerance	
Thermal	Damage Tolerance	Dama				
Strength	Strength	Containment				
Containment		Foreign Object Damage				
Aeromechanics						
Rotordynamics						
Vibration						
Loads						
Mass Properties						
Installed engine inspectability					Deterioration	
Manufacturing Process Controls					**Validated Analyses:**	

Event-based format:
- Technical review milestones
- WBS / SOW / IMP guidance

ENSIP Task (MIL-HDBK 1783B)
- SOW / IMP guidance

Detailed handbook criteria
- IMP entrance/exit criteria for tech milestone items
- Guidance for contractor – include in RFP
- Firm basis for high fidelity planning and cost estimates

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Future Efforts

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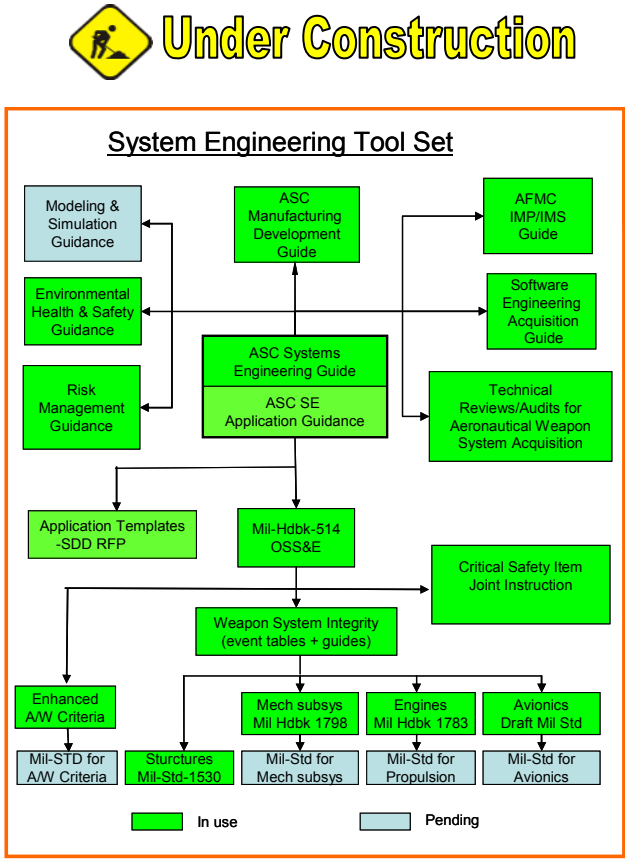
- Complete the "baseline" Tool Set
  - Additional guides: M&S, integrity programs
  - Activate & expand Application Guide, templates
  - 2005 Road Show for ASC Wings/Groups
- Ongoing efforts: update and refine tools
  - Acquisition process is not static – need to keep tools current
  - Incorporate feedback from working engineers on tool utility



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Summary

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- Sec Def Perry reform impact on SE
  - Ten years to understand and implement the paradigm
  - Tools were developed but not widely used
- ASC/EN objective: provide systems engineering guidance to program office engineers *now:* Tool Set
  - Quickly deploy available tools in web-based format
  - Incrementally refine and enhance tool set
  - Focus on execution and information content of contract
  - Emphasize event-based format
- Future: Build on the foundation, refine, improve

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