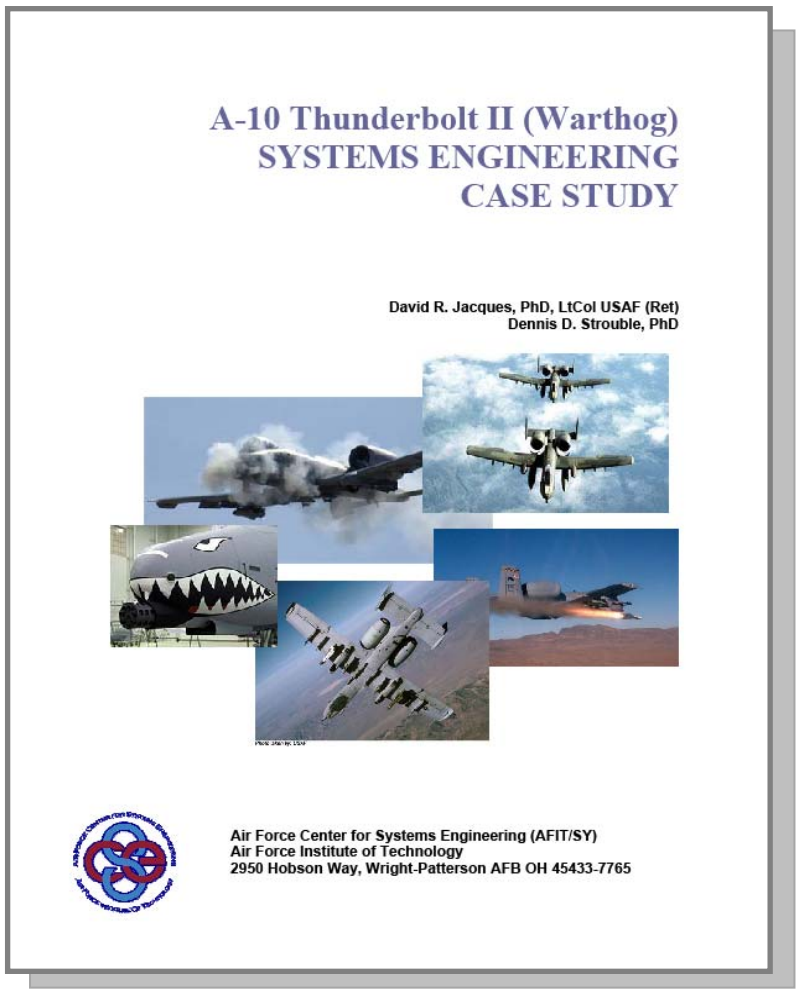


Concept Definition: A Historical Perspective

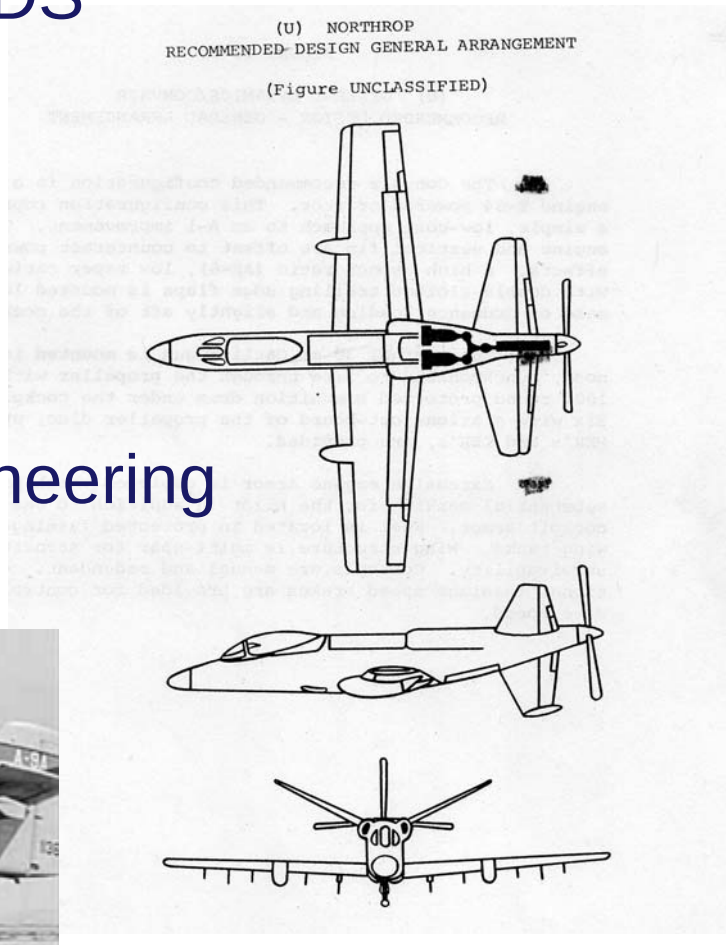
(Based on A-10 Systems Engineering Case Study)

23 Oct 08

David Jacques
Air Force Institute of Technology
(david.jacques@afit.edu)

Overview

- Mission Area Analysis Today - JCIDS
- Mission Area Analysis circa 1960's
  - The A-X Example
- A-X Concept Formulation
- Comparison and Contrast
- Air Force Center for Systems Engineering Case Studies



Decisions and Decision Making*

Decision – A Definition:

1. A choice from among a set of alternatives
2. An irrevocable allocation of resources

Steps in the Decision Making Process:

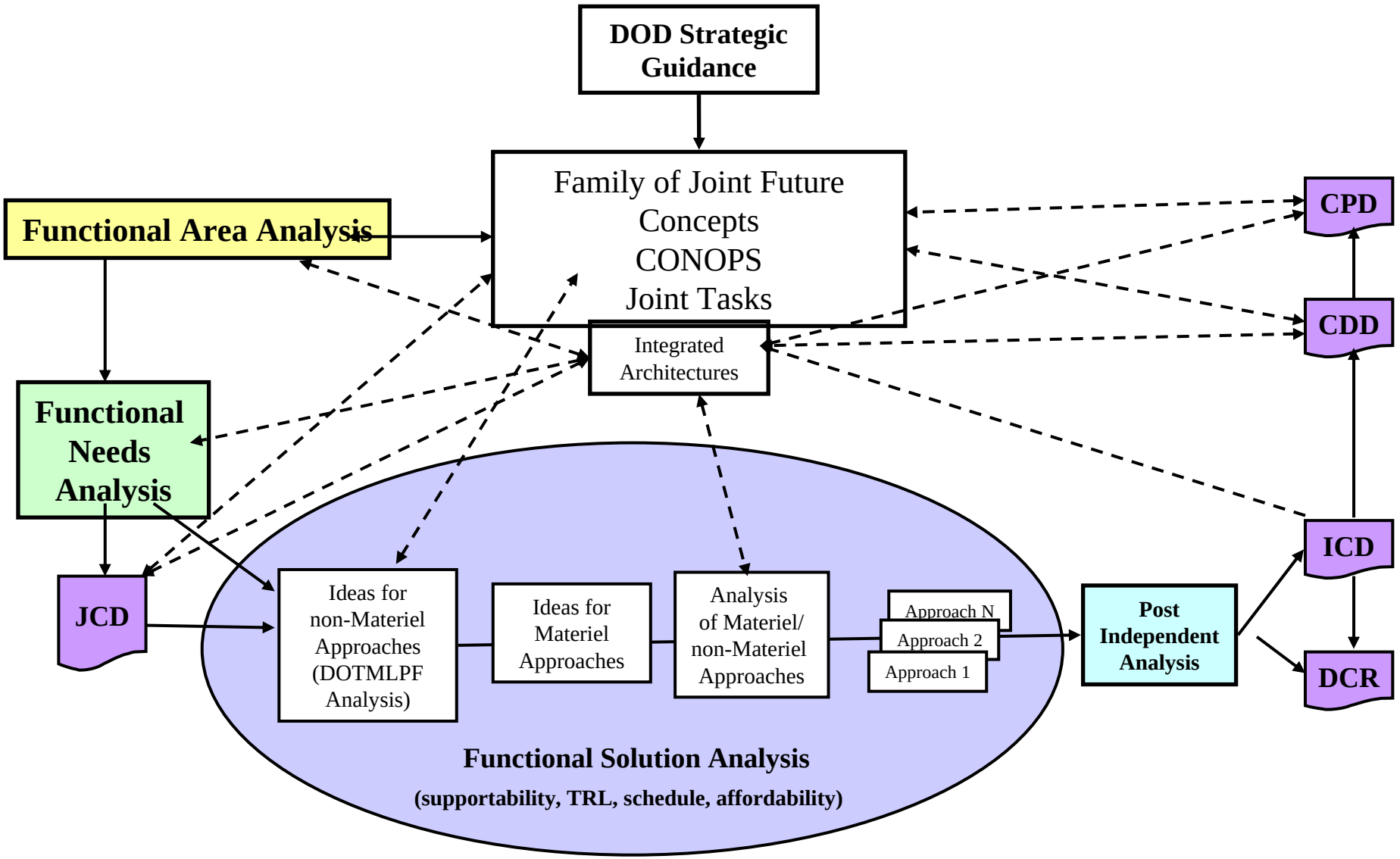
1. Formulation of preferences that, for the situation at hand, define good and bad and differentiate levels of goodness
2. Generation of a set of alternatives for consideration of choice
3. Evaluation of alternatives against the decision maker's preference
4. Selection of the preferred alternative in accordance with the decision maker's preference

* Drawn from several papers by G. Hazelrigg, appearing in the ASME Journal of Mechanical Design

Decision Making in Conceptual Design

- What are the operational capabilities that are needed?
- Should a conceptual design effort be undertaken?
- What mix of systems (legacy and new) are likely to achieve the desired operational capabilities?
- For materiel approaches (new systems), which system concept (usually a mixture of technologies) should be the basis of the design?
- Which technology for a given subsystem should be chosen?
- What existing hardware and software can be used?
- Is the envisioned concept technically feasible, based on cost, schedule and performance requirements?
- Should additional research be conducted before a decision is made?

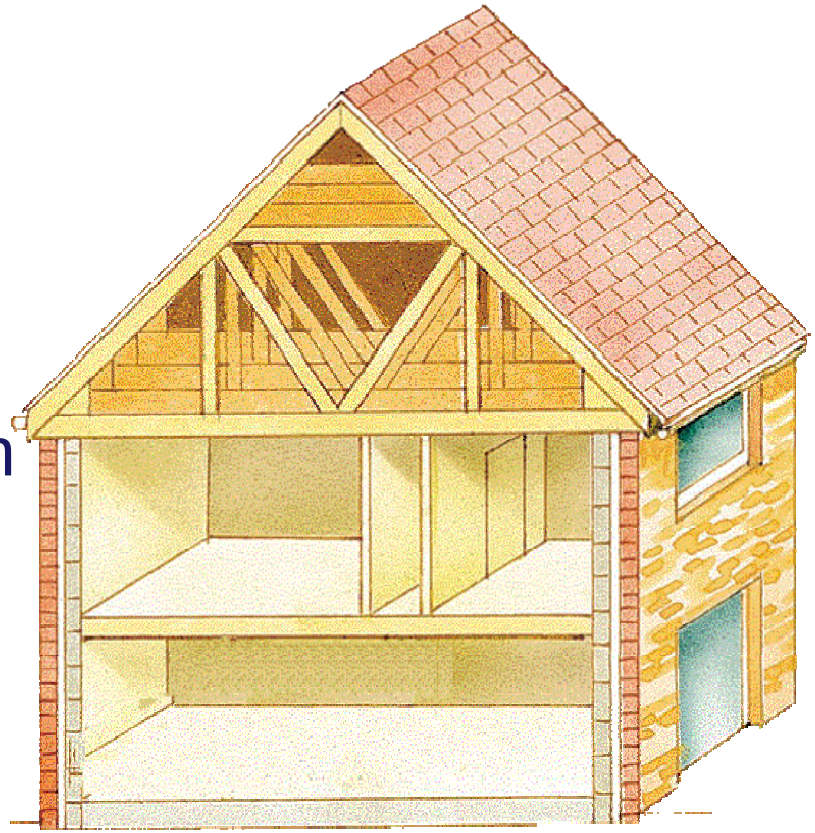
JCIDS* Analysis



* Joint Capability Integration and Development System

What is an Architecture?

"The structure of components, their relationships, and the principles and guidelines governing their design and evolution over time."
(IEEE STD 610.12 as stated in the *DoD Architecture Framework (DoDAF*)



ΑΡΧΙΤΕΚΤΩΝ *(Greek)* = Master Builder

Is JCIDS sound policy?

Recall our decision making process….

1. Formulation of preferences that, for the situation at hand, define good and bad and differentiate levels of goodness

   FAA – Establish Tasks, Conditions, Attributes and Measures

2. Generation of a set of alternatives for consideration of choice

   FNA considers current alternatives
   Early FSA identifies future alternatives

3. Evaluation of alternatives against the decision maker's preference

   FSA – Evaluates alternative approaches against FAA criteria

4. Selection of the preferred alternative in accordance with the decision maker's preference

   Concept Decision based on FSA priorities and recommendations

This actually makes sense when you consider what is supposed to be done!

Is JCIDS Really New?

- The initial instruction (and manual) came out in 2003, but is it really new?

- Let's take a trip back in time – approximately 40 years – to the Close Air Support challenges of the 1960's

Lessons from Vietnam

- Air Force largely unprepared for Close Air Support (CAS) mission
  - A-1, A-37 had insufficient payload, loiter
  - Incompatible comm with ground units

- Army doctrine evolving towards air mobile tactics
  - Increased reliance on armed helicopters
  - Initiated development of AH-56 Cheyenne

- Johnson-McConnell Agreement
  - AF retained CAS mission, but recognized role of Army helicopters for fire support
  - Army gave up large fixed-wing transports

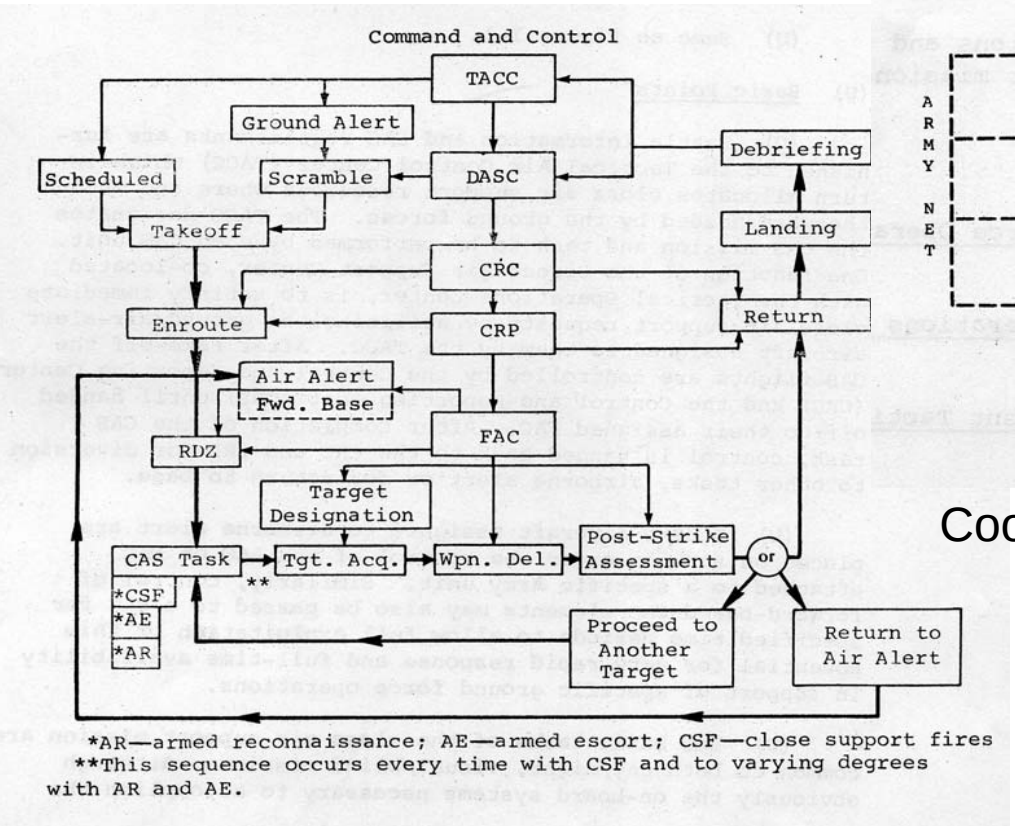
Task Definition

Three Mission Tasks

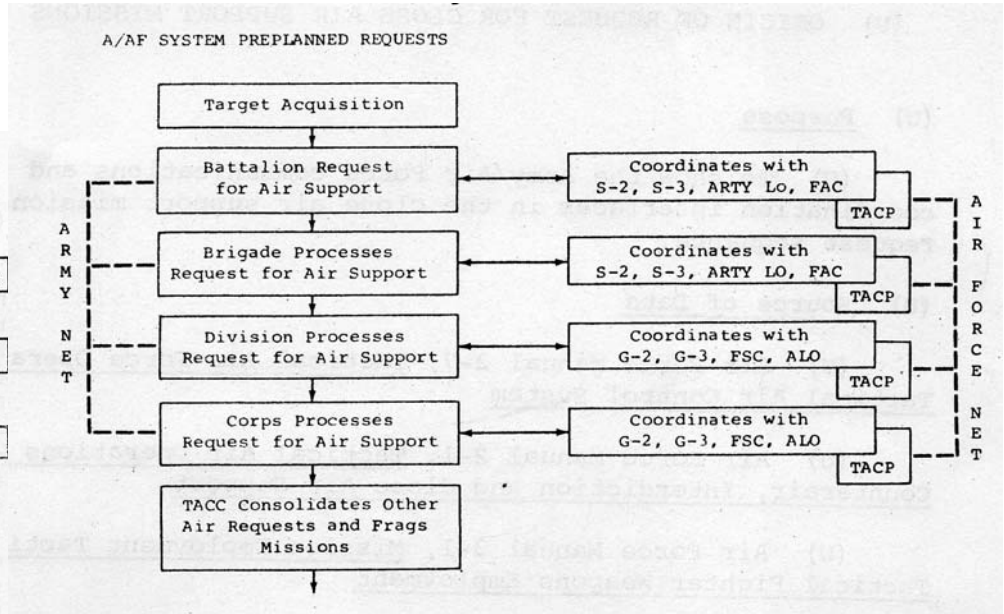
- Close Support Fire (CSF)
- Armed Escort (AE)
- Armed Reconnaissance (AR)

- CSF and AE were considered complementary
- AR involved different weapons and acquisition systems, considered a secondary A-X mission due to parallel development of AC-130 gunship

The System of Systems Perspective



The Tactical Air Control System (circa 1968)



Coordination for Pre-Planned CAS Requests

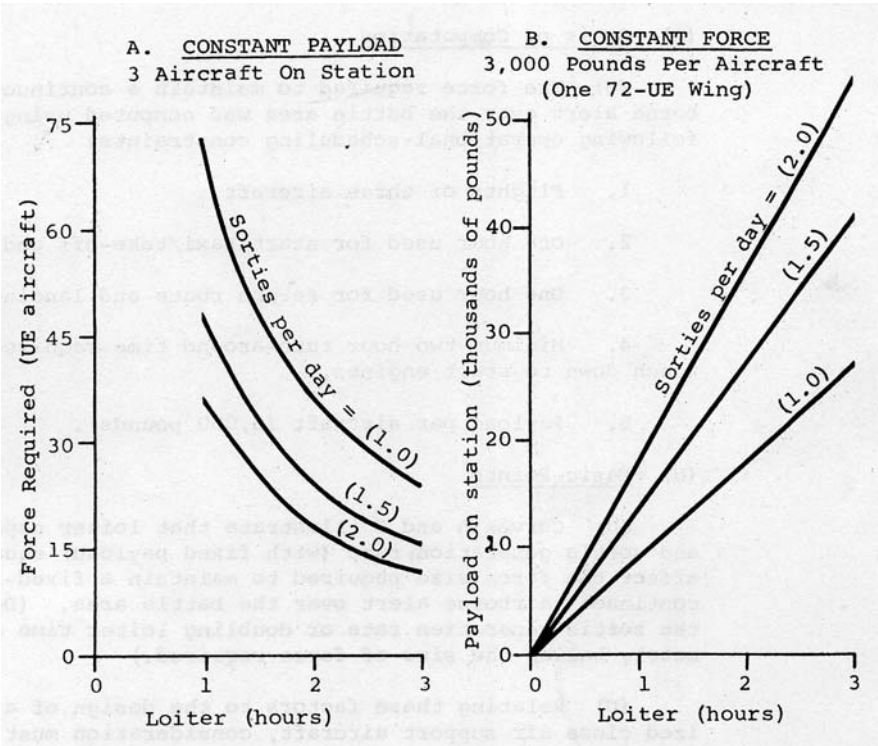
But aren't these simply elements of a mission architecture?

Attributes and Measures

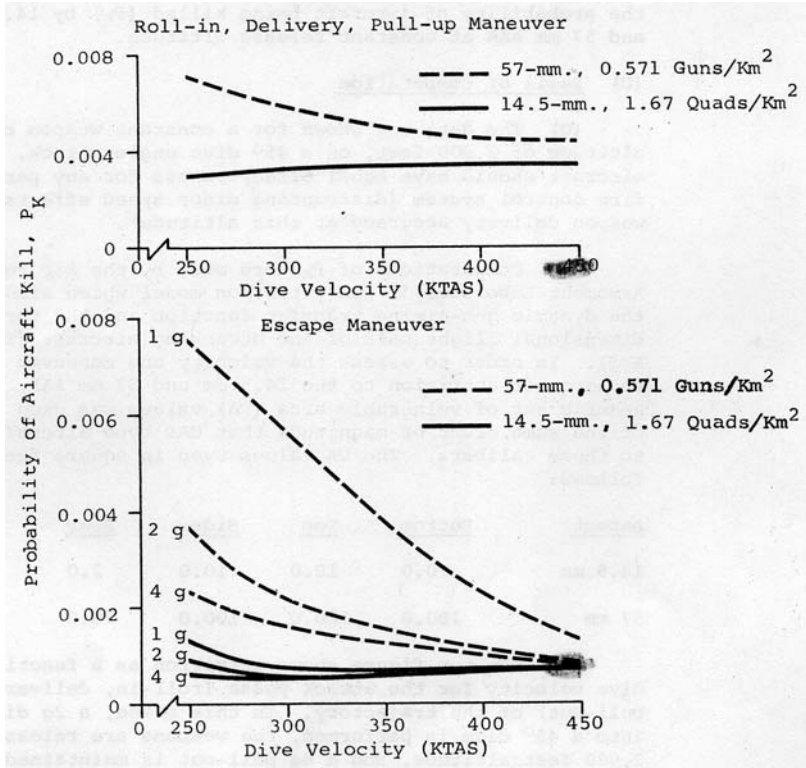
Only four key mission characteristics specified !

- ***Responsiveness*** considered not just speed, but basing locations, availability, loiter time over target, and ability to communicate with ground elements
- ***Simplicity*** emphasized ease of production, maintenance, and low cost
- ***Lethality*** made it clear that it was not an aircraft development effort, it was a weapon system development
- ***Survivability*** concerns would drive redundancy, component placement, protection systems, maneuverability, targeting systems, et.al.
- Mission characteristics drove performance parameters, which resulted in concept aircraft configurations
  - Alternatives evaluated against mission and cost effectiveness measures

Attributes and Measures (ctd.)



Impact of Loiter Time and Sortie Rate on Force Requirements



Relative Aircraft Attrition Versus Velocity and Maneuver

	AFM 26-3 PLANNING MMH/FH	ACTUAL SEA MMH/FH AVERAGE
F-4	30	33.2
*F-105	40	27.6
F-100	25	26.6
F-5	17	15.5
A-1	10	14.3
A-37	7	7.8

Maintenance Man Hours/Flight Hour for Vietnam era Aircraft

Capability of Existing Systems

- F-4, F-111 were the Air Force's primary tactical aircraft of the time
  - Both were expensive, and ill suited to CAS mission
- F-5
  - Initially the Air Force choice for a low-cost tactical fighter
  - Better air-to-air capability than A-7
- A-7D
  - Derivative of existing Navy aircraft
  - Favored by many in OSD, Congress
  - Could not carry a big gun, significantly lower loiter time
  - Would eventually be involved in a flyoff with A-10 prior to production decision
- Army Helicopters?
  - Roles and missions agreements prevented serious consideration

Aircraft Comparison

	A-1J	OV-10 (Impr.)	A-37B	A-X	A-7D	F-4C
Operating weight empty (lb) (includes crew, gun, ammunition)	13,328	9,440	6,200	20,140	19,250	31,097 w/gun pod*
Internal fuel capacity (lb)	2,280	3,680	2,974	7,000	9,750	12,818
External load capacity—with FIF (lb)	9,392	4,394	4,826	16,860	14,000	14,085
Maximum TOGW (lb)	25,000	17,514	14,000	44,000	43,000	58,000
Engines (number/type)	one R-3350	two T-76	two J-85	two T-55	one TF-41	two J-79
Useful load capacity (fuel and ordnance—lbs) for takeoff distance (Ground Run, S.L., Tropic Day) of:						
750 ft	4,000**	1,300**	3,200**	9,000	-0-	-0-
1,000 ft	6,200**	3,600	4,000**	12,500	-0-	-0-
Maximum speed, clean, S.L. (KTAS)	277	262	417	400	607	M 1.2
Best cruise speed, 5,000 ft, maximum ordnance (KTAS)	170	170	265	240	315	420
Ferry range, unrefueled (NM)	2,800	2,600	1,560	2,600	2,600	1,600
Number of ordnance stations	15	7	8	10	8	5
Internal guns (number/caliber)	four 20-mm	four 7.62-mm	one 7.62-mm	one 30-mm	one 20-mm	*(one SUU-16 20-mm pod)

**Cannot land in this distance at any weight.

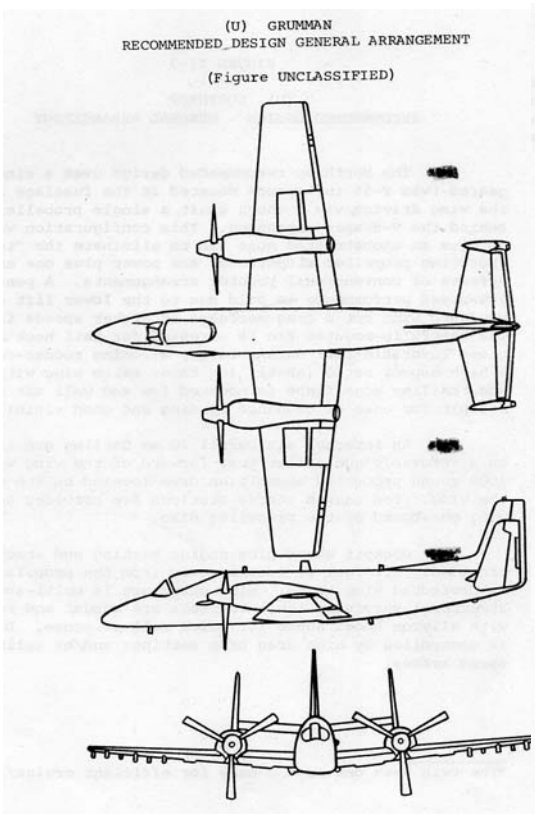
A-X Concepts

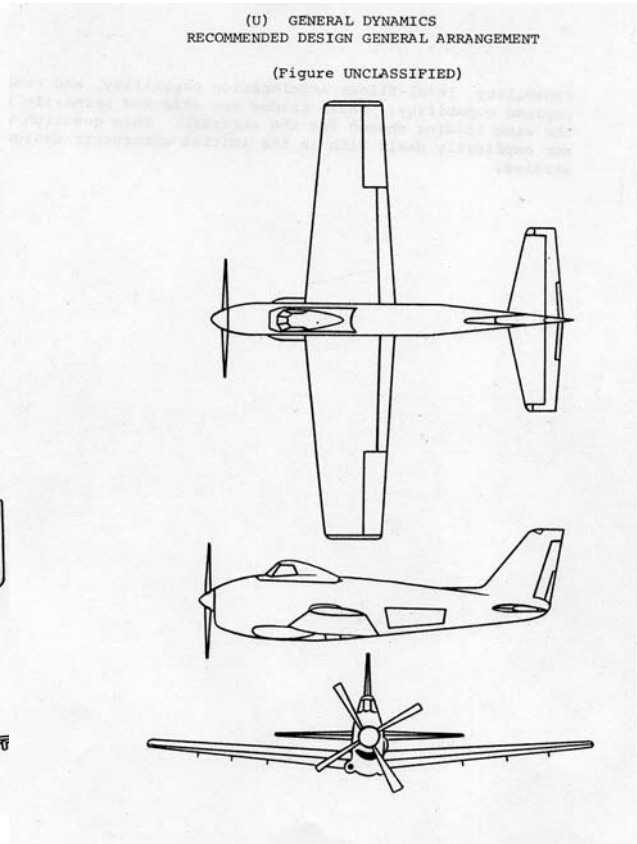
Requirements from Dec 1966 Requirements Action Directive

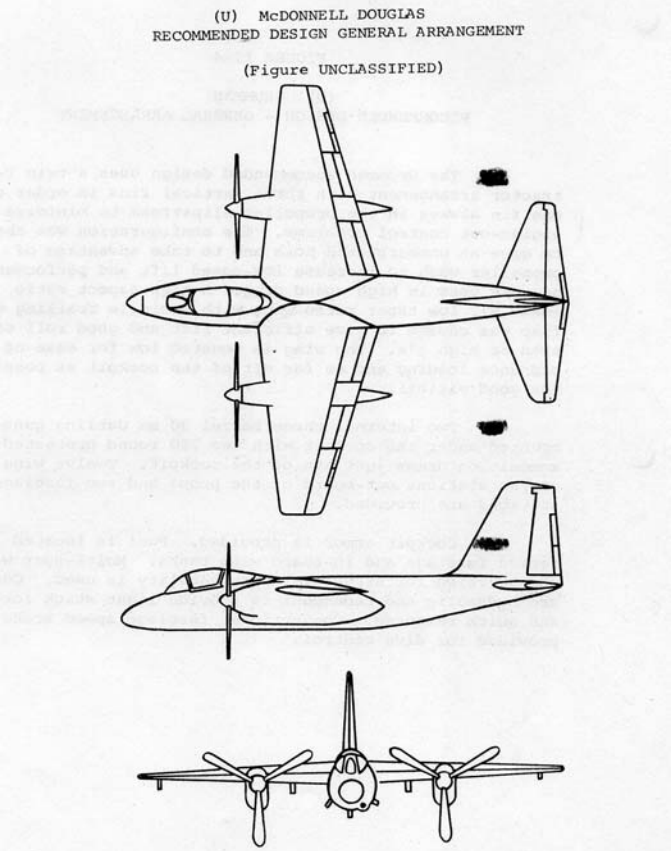
Performance Parameter	Desired	Required
Gross Weight (lbs)	22,500	30,000
Payload - Mixed Ordnance (lbs)	8,000	6,000
Combat Radius (nautical miles)	---	200
Loiter Time @ Combat Radius (hrs)	---	2
Min Maneuvering Speed @ 5000 ft (knots)	120	150
Turn Radius @ Combat Weight (ft)	1,000	2,000
Max Speed @ Sea Level w/ Ext. Ordnance (knots)	550	450

- Concept design studies conducted in 1967
  - Resulted in two government configurations, and four contractor configurations
- Concept determined to be feasible within existing technology
  - Most configurations used turbo-prop designs
  - Identified risk elements included gun/ammunition development and integration, and early IOC
  - Lean avionics packages defined to keep costs down
- Concept Formulation Package (predecessor to Initial Capability Document) completed in 1968

A-X Concepts







Notes: Significant design changes occurred during Concept Definition (now referred to as Concept Refinement)

- Single or twin turboprop propulsion gave way to twin turbofan (leveraged Navy S-37 aircraft development)
- Payload essentially doubled to 16,000 lbs – led to aircraft size/cost growth

JCIDS 40 Years Early?

Did the A-X concept formulation adhere to (in retrospect) JCIDS principles?

Yes … , kind of …

- Clear definition of tasks, conditions and measures (FAA)
- Consideration of a range of existing Air Force systems to provide the needed capability (FNA)
- Concept formulation traceable to previously defined tasks, conditions and measures (FSA)

Shortcomings

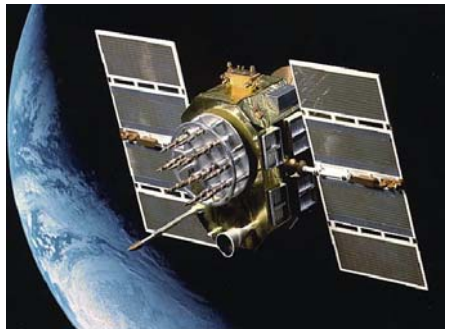
- No serious consideration of the full range of joint warfighting concepts to meet the capability needs

Summary

- The A-X concept formulation was rigorous and traceable to user needs
- While full consideration of joint concepts may not have been done, the emphasis was not on joint capabilities
- Aircraft has performed well, and is still in service today

Air Force Center for Systems Engineering Case Studies

Hubble Space Telescope



GPS (Global Positioning System)

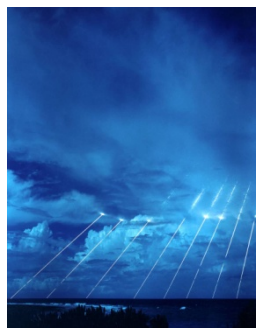
F-111 Aardvark

C-5 Galaxy

B-2

TBMCS (Theater Battle Management Core Systems)

A-10



Peacekeeper Intercontinental Ballistic Missile

Website:
http://www.afit.edu/cse/

Ongoing & Future Case Studies

International Space Station

Underway

MH-53J/M Helicopter

FY09 Option

E-10

FY10 Option

Global Hawk

Underway

KC-135 Simulators

FY09 Start

T-6A Texan II

FY10 Start

Questions?