Headquarters U.S. Air Force

Integrity - Service - Excellence

ICEAA

Air Force Cost Analysis Agency

Space Analysis of Alternatives

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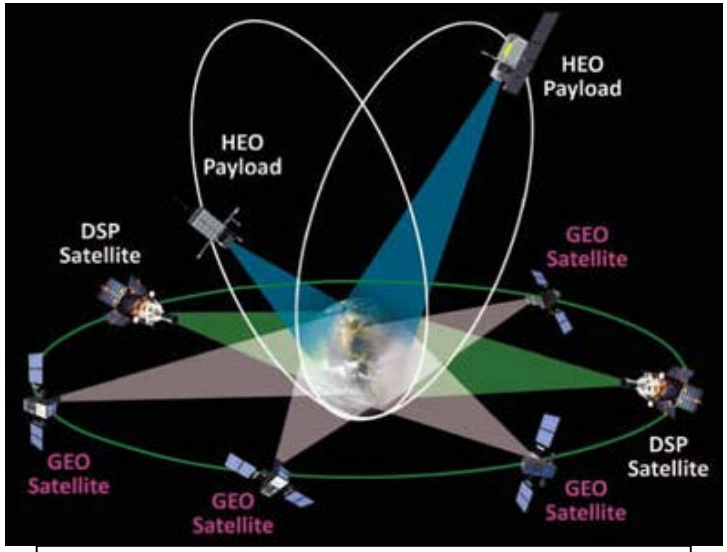
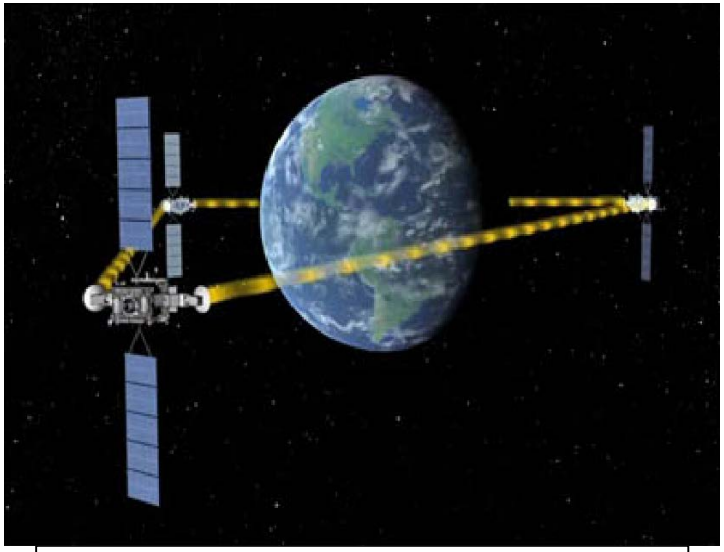
Outline

- Background
- AoA Basics
- AoA Methods
- Decision Support
- Observations





An artist's concept of the three AEHF satellites. Credit: Lockheed Martin

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AoA Cost Efforts
Space Portfolio

- **Prior AoA's have not involved CAPE/CA or PA&E/RA**
  - **'94 Summer Study used to justify SBIRS concept**
  - **SAF/AQ proposed National Team concept after loss of a MILSTAR satellite for accelerated replacement concept (led to AEHF)**

- **New Paradigm - Cost Assessment Working Group (CAWG) report directly to CAPE(CA)**
  - **Provided layer between CAWG and AoA Study Director to provide independent cost analysis**
  - **Included all cost elements (i.e., Space, Ground, Launch, Sustainment)**
  - **Balanced promise of new technology with historical development cycles and realistic technical baselines**
  - **Takes away ability of CAPE to question AoA sufficiency from a cost perspective**

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AoA Cost Efforts (cont.)

- CAPE approached AFCAA and asked them to lead CAWG for two space AoAs: (1) Space Based Infrared System (SBIRS) Follow-on and (2) Protected Satellite Communications Services (PSCS)
  - Previous efforts internal to Air Force Commands
  - Previously AFCAA played either no role or advisor role
- AFCAA estimating process used to ensure consistent results
  - Independent tech assessments (weight, power, heritage, software)
  - Realistic acquisition strategies
  - Independent schedule assessments (development, build)
  - Broad involvement from DoD Agencies and IC community enabling wide data access and defendable cost database regressions
  - Consistent application of methods to mitigate bias toward an alternative
  - Collectively solved previous AoA weaknesses and criticisms

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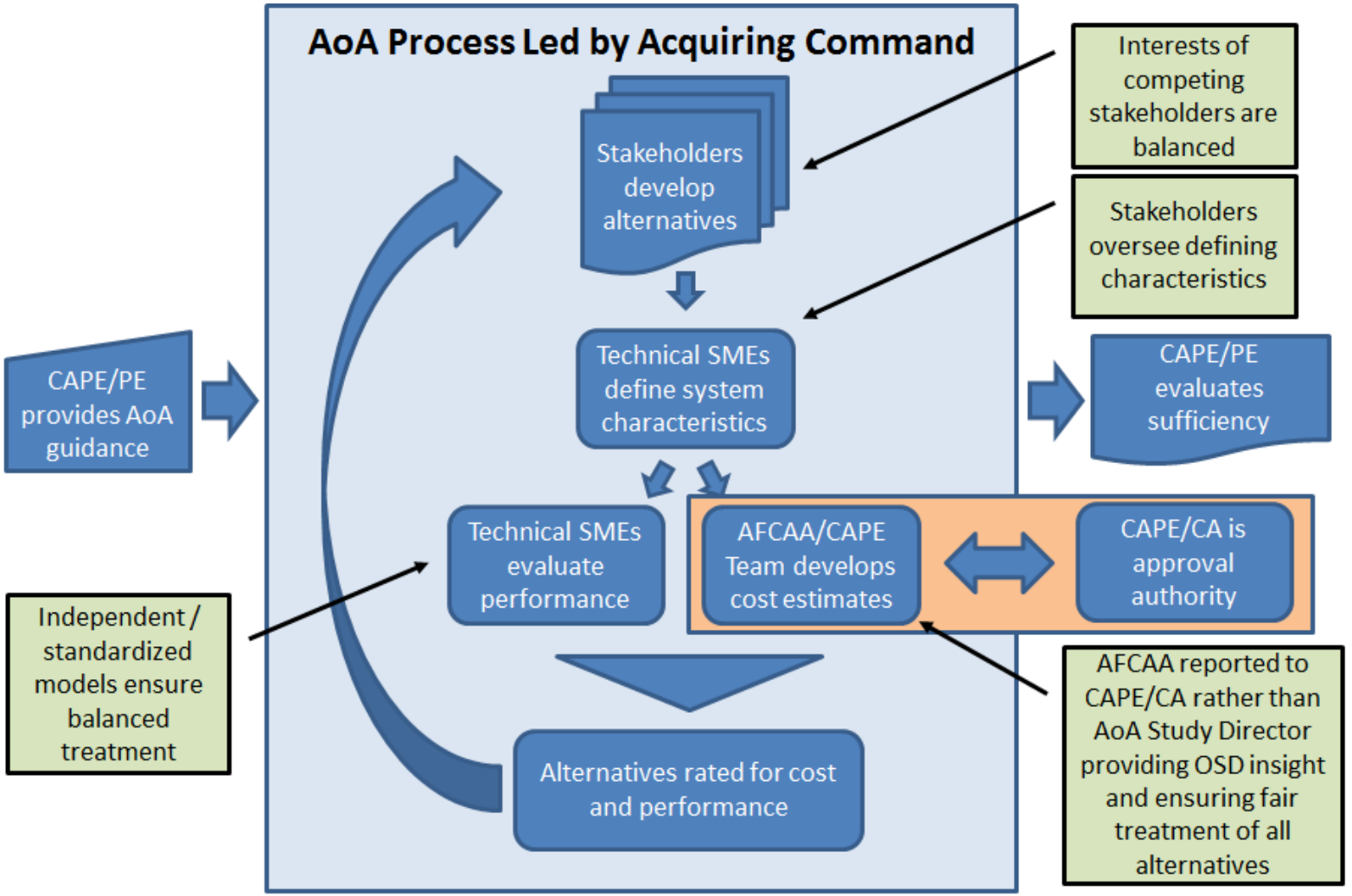
AoA Model – SBIRS FO & PSCS



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AoA Study Team Example

- Study Plan
- Study Guidance
- ADM

SAG Co-Chairs
OSD/CAPE & OUSD/AT&L/SSI

Study Director
AFSPC/A5F & NRO/MID

Working-level Integrated Product Team (WIPT)

Study Technical Leads
AFSPC/A5F & NRO/SED

CAPE | AT&L/SSI | OAS | MDA | NGA

Study Integrator

Technical Advisor / RAT Lead

Effectiveness Analysis WG (EAWG)	*Cost Analysis WG (CAWG)	Technology & Alternatives WG (TAWG)	Threats & Scenarios WG (TSWG)	Operational Concepts WG (OCWG)
AFSPC/A9	AFCAA	SMC/XR	MDA & AFSPC/A2	AFSPC/A3 & NGA

Ground | Space | Communications

CAWG is a direct report to OSD/CAPE

Proposed Joint Participation

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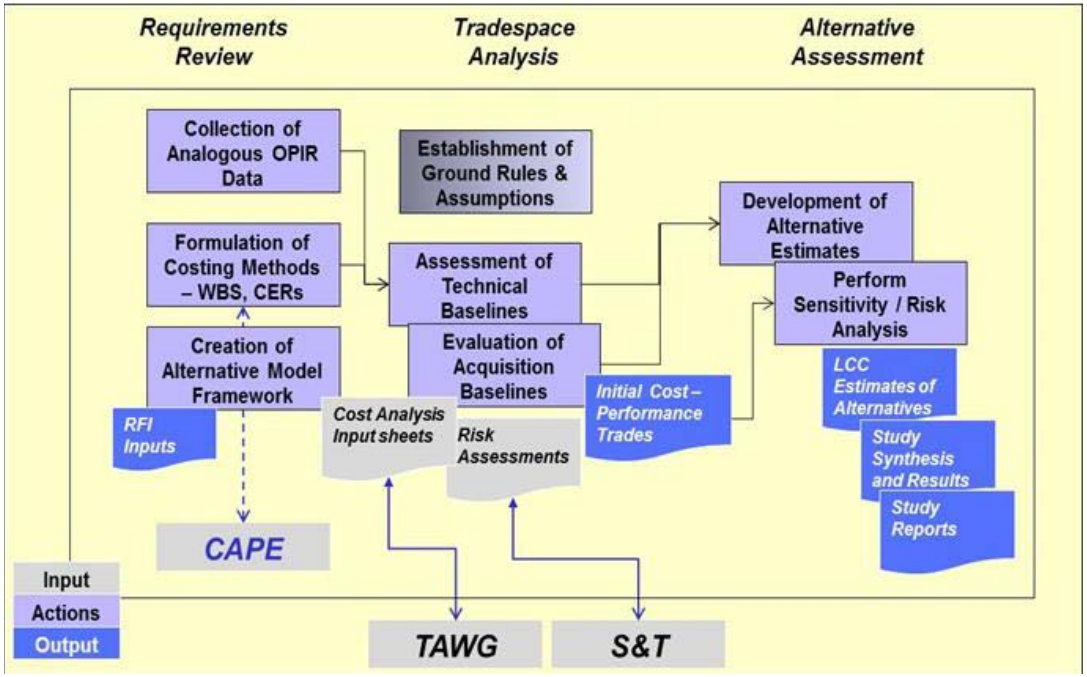
Cost Process

- AoA Study Plan defined scope and goals of analysis – think of this as "what questions are we trying to answer"
- Collective Team defined Ground Rules and Assumptions
- Estimating process even handed across all possible solutions
- Creative products to support Trades and Assessment of Alternatives



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AFCAA CAWG Leadership

Unique Strengths

- Early CAPE Involvement
  - Collaborative Collection of Data
  - Formulation of Defensible Methods
- Cross Agency Cost Team
  - IC, MDA, and Air Force participation
  - Analogous programs' data and methods
  - Increased Perspective
- AFCAA Best Practices
  - Schedule estimating
  - Advanced Phasing methods
  - Satellite Sizing Model
  - TRL / Heritage calculators
  - Phase A methods
  - Ground / Sustainment modeling
  - Benchmarking analysis

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AoA Methods

- Independent Tech Baseline Assessments
- Heritage Assessments
- Schedule Analysis
- Cost Analysis Methods
- Cost Data Sheets
- Cost Model Development

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Independent Technical Baseline Assessment

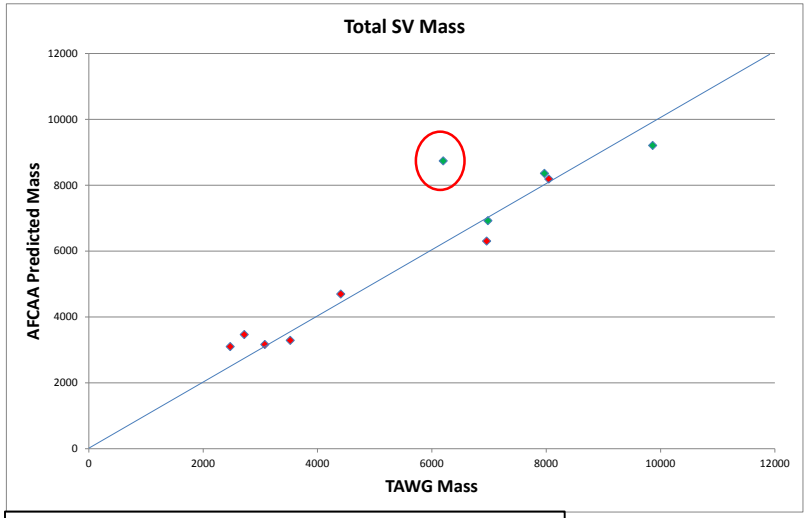
Satellite Sizing Model
4/1/2014
INPUTS in YELLOW

Orbit/General Inputs		
Orbit Apogee Altitude	35,786	km
Orbit Perigee Altitude	35,786	km
Orbit Type	GEO	Pick One
Design Life	10	Years
Small Satellite (< 2000 lbs)?	No	Pick One
EPS Inputs		
Required Inputs		
Ave Day Power, Pd (EOL)	1,755	Watts
Ave Eclipse Power, Pe (EOL)	1,755	Watts
Peak Power (EOL)		Watts
Cell Type	Silicon	Pick One
Average Incidence Angle	4.60	degrees
Articulated Arrays	Yes	Pick One
Power Regulation	DET	Pick One
Battery Type	NiH	Pick One
Optional Inputs		
Cell Efficiency		%
DoD	75.0%	%
EPS Margin	0.0%	%
ADCS Inputs		
Pointing Accuracy	0.05	degrees
Agile spacecraft	1	Pick One
Number of attitude reference units	9	Input
Propulsion Inputs		
Required Inputs		
Propulsion Required?	Yes	Pick One
Delta V	1654	m/s
Propellant Type	Bipropellant	Pick One
Optional Inputs		
ISP		
Total Impulse		
Delta V Margin		
TT&C Inputs		

Total	Mass (lb) Predicted w/Growth	Mass Growth
Total Payload	**1,642**	
Communications or Navigation Payload	172	24%
Electro Optical / Infrared Payload	1,364	45%
Hosted Payloads (e.g., Environment, SSA)	106	16%
Total Bus *(for sizing only)*	6,549	
Total Bus (dry weight)	**3,221**	
Structures, Mechanisms, Thermal	1,264	
Electrical Power	905	
Attitude Determination and Control	308	
Propulsion (w/o propellant)	634	
Propulsion (w/propellant)	3,962	
Propellant	3,328	
Tracking Telemetry and Command	110	
Total SV Dry	4,862	
Total SV Wet	**8,190**	

Close Space Vehicle Design

4,862 <-- Seed
0.0 <-- Difference

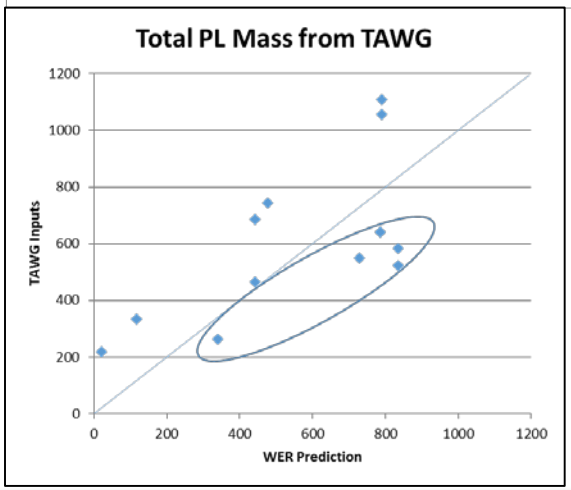


EO/IR Payloads

	Description	Value	Units
	Inputs		
(U)	Aperture	28	cm
(U)	Number of FPAs	14	number
(U)	Unobstructed	1	Y/N
(U)	Max wavelength	5	microns
(U)	Design life	120	months
	Reserved	0	Y/N

W = a * (ap)^b * (1+c*# of sensors or FPAs)*d^(off axis)*(maxL)^e* DL^f

(U)	Weight		lbs



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Heritage Assessments

Consider Technology & Derivative Impacts

Typical Changes with New Payload

EPS
- Change in orbit
- Change in duty cycle, depth of discharge
- Change in avg. power to payload
- Change in number or type of regulated voltages required

Propulsion
- Change in orbit
- Change in weight, CG, drag
- Change in design life/delta-V

ACS
- Change in payload pointing requirements (accuracy, stability, knowledge, slew rate, direction, settle time, drift)
- Change in center of gravity (CG), inertia matrix over time
- Change in thermal or power needs
- Change in mission profile and solar/magnetic models

Structure
- Change in weight of payload
- Change in weight/CG of other subsystems, mounting location of components
- Change in launch vehicle

Comm/TT&C
- New data rate
- New relay or ground location
- New access/pointing requirement
- New orbit/range/elevation angle
- Different BER requirement
- New command list, new requirement for stored commands
- New telemetry list
- New RF and EMC issues
- Different reliability requirements

Thermal
- Different orbit
- New payload, bus electrical energy dissipation requirements
- Solar-array or battery changes

Typical Cost Impacts

EPS
- Assess changes and new operating constraints
- Develop new power budget
- Assess and simulate battery temperature, rate of charge/discharge, degree of overcharge
- Resize the battery and/or solar array, charge control logic, etc.
- Iterate and document

Propulsion
- Develop new propellant budget
- Develop new valve/line layouts
- Reasses number, location, orientation of thrusters
- Resize tanks

ACS
- Reassess attitide-control budget, disturbance torques
- Assess need for new control modes
- Definen and implement determination and control algorithms
- Define system-level requirements by control mode
- Add s ensors/actuators as needed
- Iterate and document

Structures
- Develop new static and dynamic structural models
- Conduct new mode-survey test, loads analysis
- Stiffen via cross-braces, new materials
- Conduct new ascent, separation, and on-orbit dynamics analysis
- Iterate and document

Comm/TT&C
- Implement new encoding/modulation scheme
- Update FOV analysis
- Reassess link bud
- Conduct subsyste
- Select new
- Assess tin
- Reexamin
- Select new
- Develop, i
- Assess an
- Iterate and

Thermal
- Develop n
- Assess ne
- Reassess
- Validate th
- Iterate and

%ND		Factor to consider in addressing %New
60	y or n	
0	y	System specification complete, system design review (SDR) complete
0	y	System requirements flow down through work breakdown structure (systems engineering begins)
0	y	System interface requirements known
0	y	Hardware requirements analysis complete - includes embedded software
0	y	Draft design drawings (mechanical / electrical) are complete to PDR maturity
10	y	Engineering Model (EDM) required to verify design meets functional requirements
10	n	Test procedures understood, Test Plan complete
10	n	Tooling in place to support build and test of ProtoQual and EDM
10	n	Design drawings (mechanical / electrical) are complete to CDR maturity
10	n	Test equipment / software in place to support unit level Proto-Qual and Acceptance testing
10	n	Manufacturing process controls / configuration management program in place
0	y	Component parts qualification completed OR comp qualification testing not required
0	y	Unit level qualification testing completed OR ProtoQual / acceptance testing required

Development costs informed by unbiased heritage assessments

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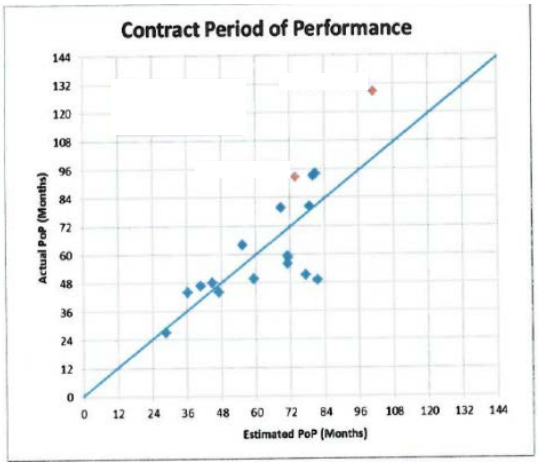
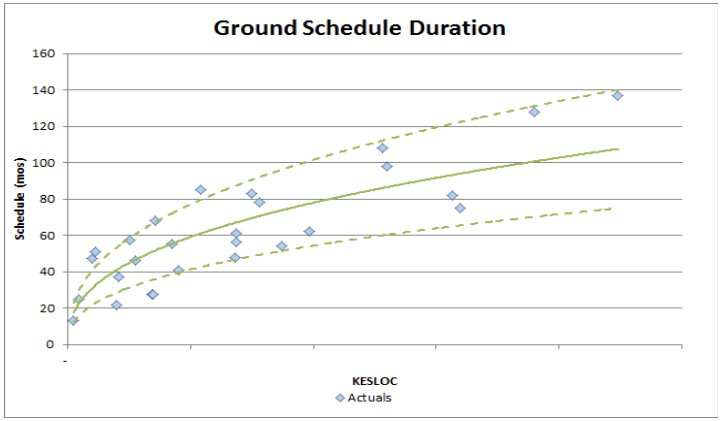
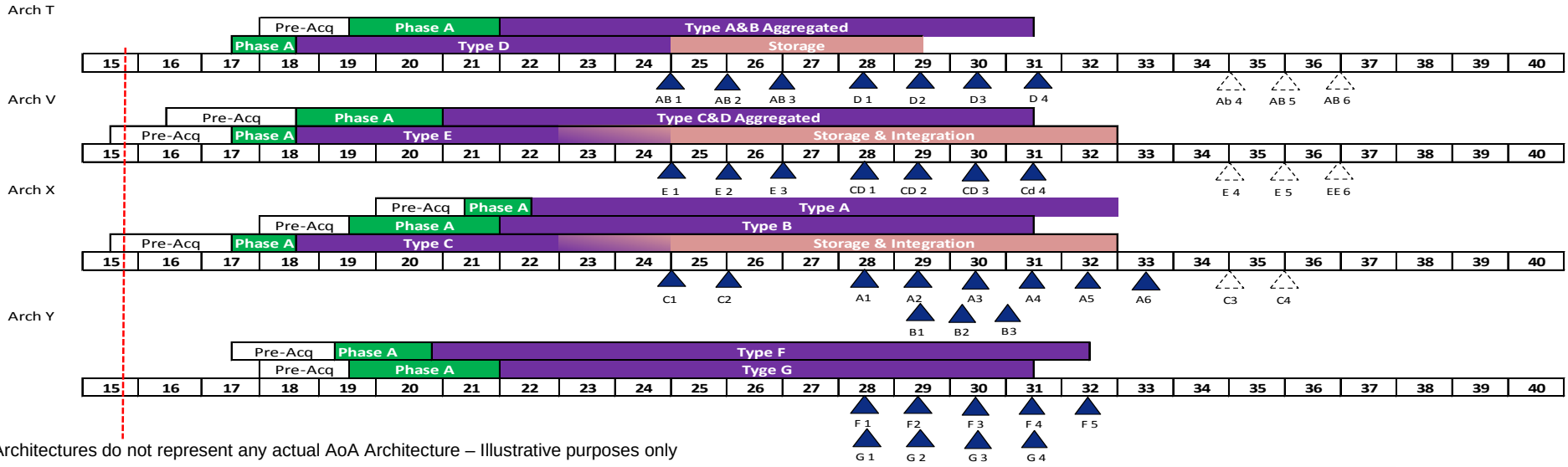
Schedule Analysis Considers Contract Strategy







*Architectures do not represent any actual AoA Architecture – Illustrative purposes only

Independent analysis ensures achievable schedule baselines

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Cost Methods

- Primary and Crosscheck methods selected
- Selection criteria:
  - Broad application to many alternatives (no bias)
  - Predicts the Air Force Missile warning mission well
  - Predicts Protected SATCOM mission well
  - Cost Drivers need to be definable/understood by tech team

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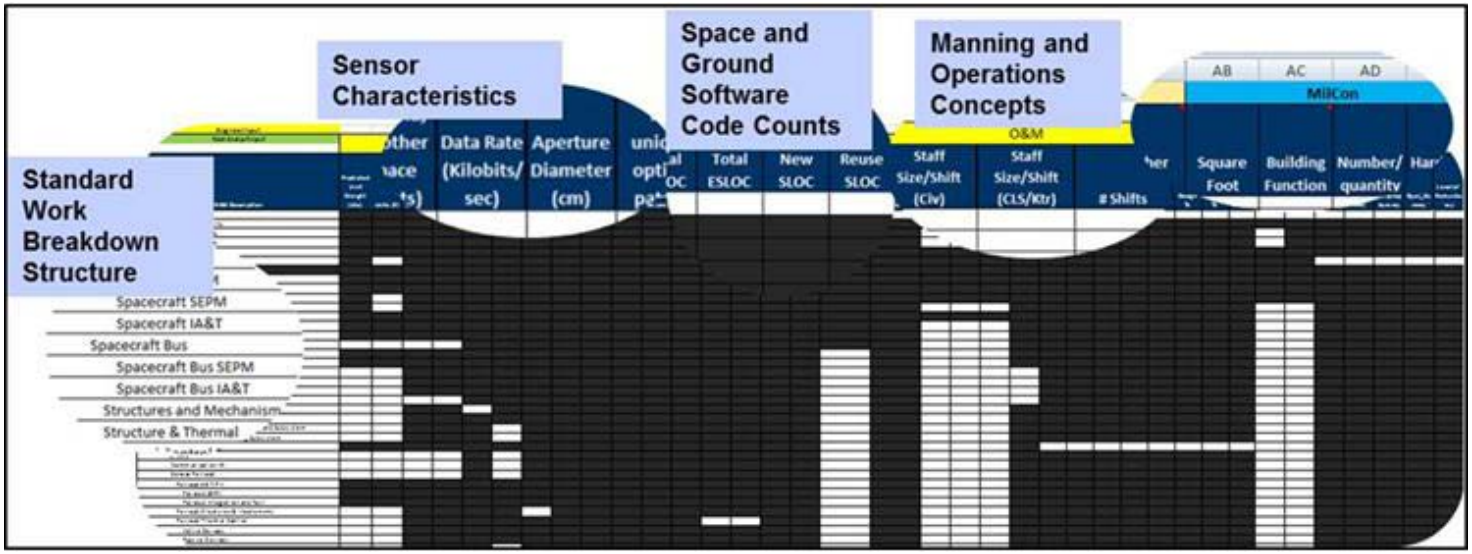
Cost Data Sheets

- Leveraged previous experience with Technical team
- Cost Data sheets populated with Estimate WBS and all required Cost Drivers and CER inputs
- Key process enabler:
  - Consistent and early documentation of Cost team needs
  - Provided a complete Tech baseline description and configuration control of various alternatives



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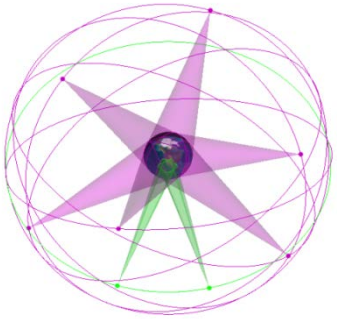
Decision Support
Tools and Outputs

- "Baseball Cards"
- Comparison Metrics
- Model Outputs
- Risk & Opportunities
- Near-Term and Long-Term Affordability

Architecture X "Baseball Card"



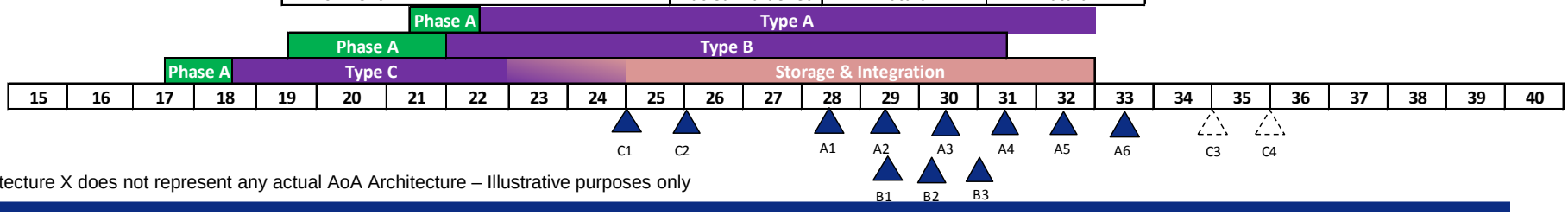
Type A Payload:
Tech Parameter A
Tech Parameter B
Type B Payload:
Tech Parameter C
Tech Parameter D
Type C Payload:
Tech Parameter E
Tech Parameter F

Architecture X				
Alternative Mean Estimate (BY14$M)	**Cost to Deploy**	**SV Type A**	**SV Type B**	**SV Type C**
Space Vehicles	**11**	**6**	**3**	**2**
Reference Number		Ref-A	Ref-B'	Ref-C'
Total Program Costs	$ 31,432	$ 10,312	$ 2,020	$ 1,700
Space Segment Acquisition Cost	$ 7,540	$ 5,310	$ 1,230	$ 1,000
Phase A	$ 130	$ 80	$ 20	$ 30
Hosting Fee	$ -	$ -	$ -	
Non-recurring	$ 2,350	$ 1,500	$ 500	$ 350
Recurring	$ 4,500	$ 3,650	$ 350	$ 500
Storage	$ 60	$ -	$ 60	$ -
Ground Mission Control	$ 500	$ 80	$ 300	$ 120
Launch Segment	$ 1,900	$ 1,500	$ 400	Hosted
Operations & Sustainment	$ 3,692	$ 2,602	$ 640	$ 450
Current Baseline	$ 1,600	$ 1,200	$ 400	$ -
Additional O&S	$ 2,092	$ 1,402	$ 240	$ 450
Other Government Costs	$ 1,300	$ 900	$ 150	$ 250
Terminal Segment	$ 15,500			
Aerial Layer	$ 1,500			
Bus Weight (Lbs)		6,250	2,300	Hosted
Payload Weight (Lbs)		1,800	950	240
Wet Mass (Lbs)		14,077	--	--
Payload % New Design		75%	25%	50%
Design Life		14	10	14
Acquisition Strategy		Open Competition	Sole Source	Sole Source
Launch Vehicle		Atlas V 551	Hosted	Hosted
Environment		Nuclear Hardened	Natural	Natural

- FOC Arch Fielding
- Replenishment

- **ICEAA Architecture X**
  - **Same capability as SCEA**
  - **Updated to leverage today's technology**
- **Acquisition Strategy**
  Competitive award of ____
  - **Sole Source _____**
- **SV Type C**
  - **Adds capability to XYZ**
  - **Replenishment tied to longer design life**
  - **Not in other Architecture**
- **Additional Risk**
  - **Schedule concerns**
  - **Industry base**
- **Opportunities to combine contracts**

Arch X



*Architecture X does not represent any actual AoA Architecture – Illustrative purposes only

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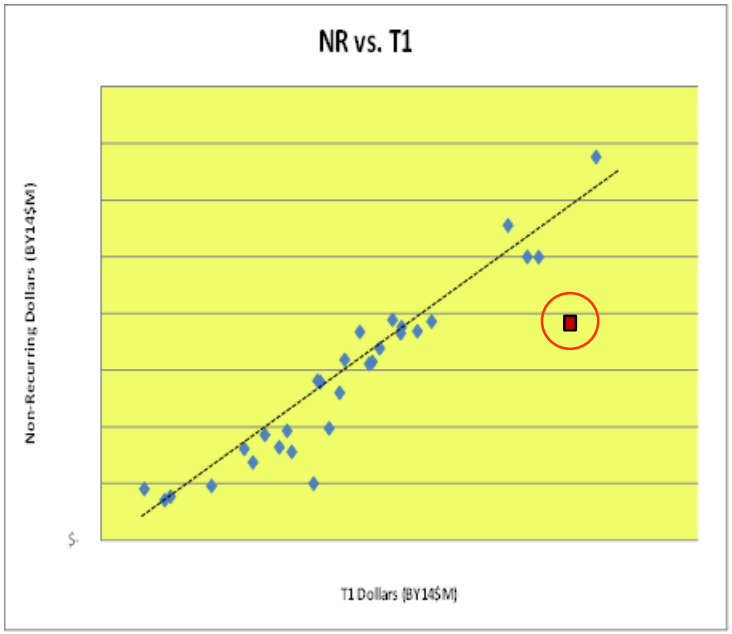
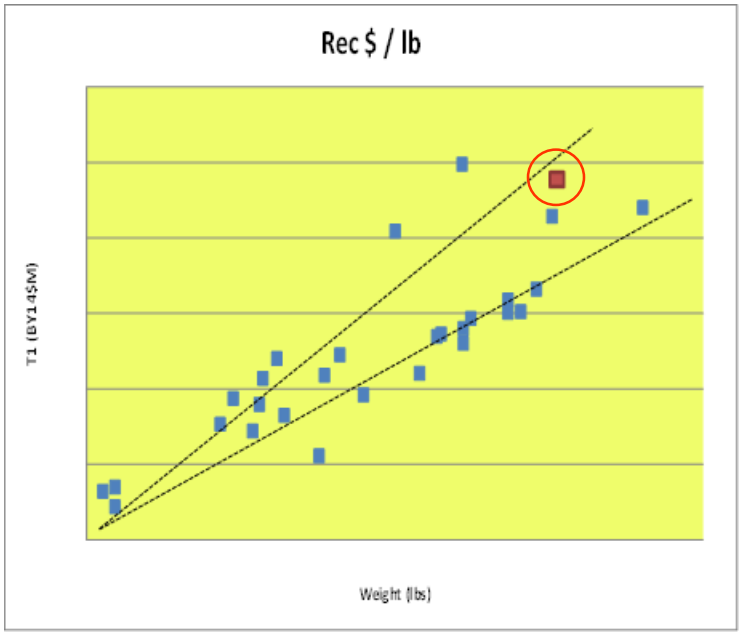
Metrics Comparisons

- Comparisons of numerous cost estimates can be difficult
- Plotting and comparing different metrics can help identify relationships, trends, and differences





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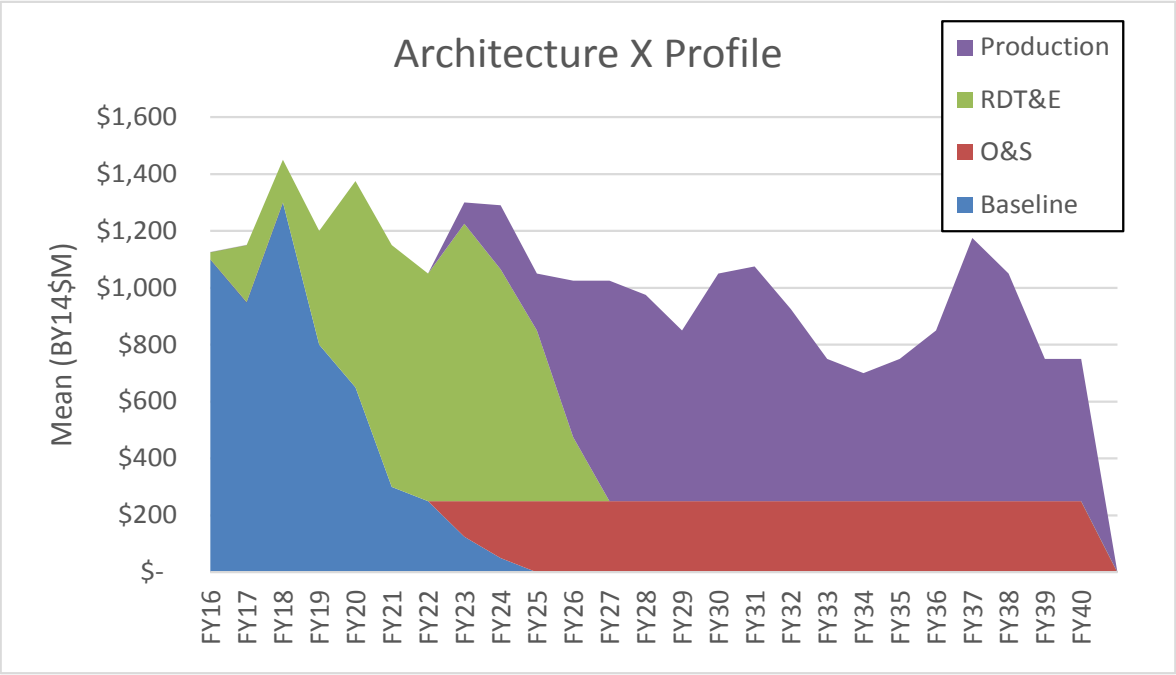
Model Outputs

- **Sand charts presented for each alternative to show investment requirements by appropriation**



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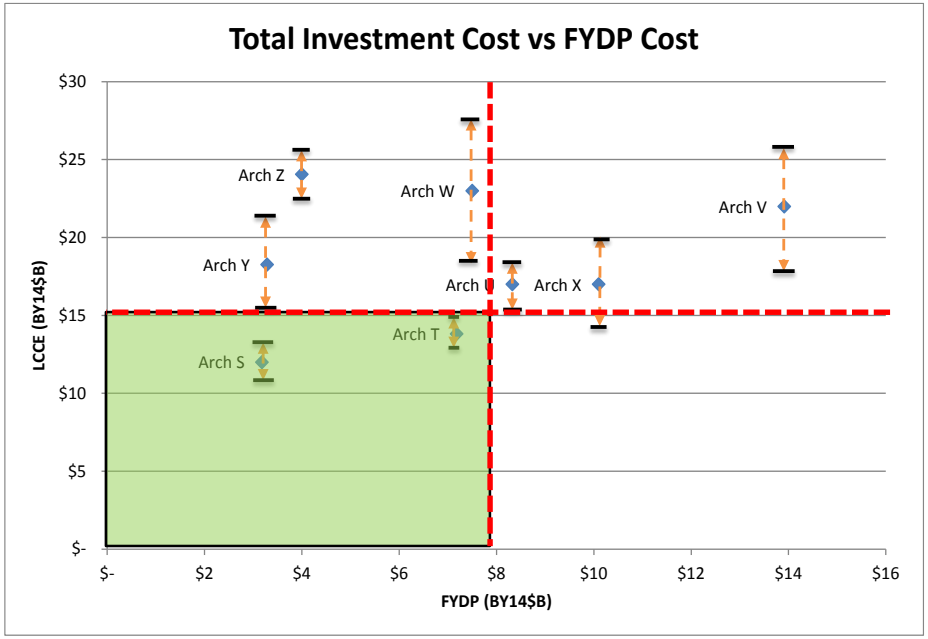
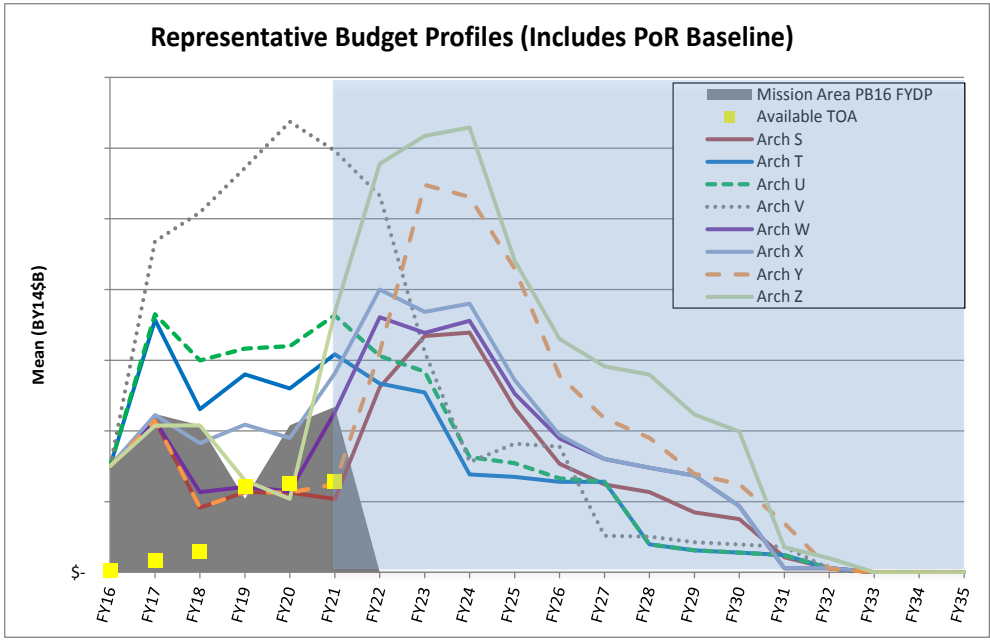
Space Affordability
Near Term and Long Term





- **Balanced near term / long term affordability concerns for decision makers**
- **FYDP affordability driven by acquisition timeline, not contents of architecture - any architecture could be affordable in FYDP with later start – assumes risk**
- **Air Force must be cognizant of "bow-wave effect" in out years**

**Architectures do not represent any actual AoA Architectures – illustrative purposes only*

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AoA Observations

- Movement away from current Program of Record comes with various degrees of cost and schedule risk
- Recognized opportunities are available to do things better going forward (e.g., commercial launch, ground automation, block buys)
- Concluded benefits of disaggregation come at cost premium
- Recommended enterprise resiliency strategy, notes degree of resilience does not discriminate among the Architectures
- Included cost of Ground and Comm segments plus Sustainment, which have been historically overlooked in prior AoAs – big cost
- Methods were data driven using relevant programs, does not assume all historical problems will repeat – not overly conservative
- Results represent most likely outcome given experience in these mission areas, not intended to direct PM cost and schedule goals