



# ***Methodology for Assessing Reasonableness of Large Scientific Facilities' Costs***

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***ICEAA Workshop  
May 15-18, 2023***

Approved for public release. OTR 2023-00722.



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# Introduction

## The challenge of assessing reasonableness of scientific facilities

- A review of reasonableness is an assessment: Whether the components of the project estimate are reasonable and the plan as a whole is reasonable
  - *Determined by assessing each Work Breakdown Structure (WBS) item in project estimate against tailored “reasonableness ranges”, which are based upon independent cost analysis and informed by the technical knowledge of Subject Matter Excerpts (SMEs)*
  - *While not as detailed as an Independent Cost Estimate (ICE), a review of reasonableness is a thorough independent assessment of the quality of a preexisting project estimate*
  
- Large scale scientific facilities exist to enable research in numerous fields and each tends to be uniquely tailored to intended research
  - *Observatories and Segmented Telescopes*
  - *Radio Frequency Antenna Arrays*
  - *Scientific Sensor Facilities*
  - *Data Networks*
  
- Attempting to assess reasonableness for such facilities presents many challenges
  - *Diversity of facility and equipment types*
  - *Availability of applicable data and models*
  - *Developing tailored criteria to capture details at low and high levels*
  - *Budget category characterization and constraints*

	Labor					Equipment	Travel	Materials & Supplies	Information Technology	Sub-Contractors	Total Direct Costs
	Project Management	Technicians and Scientists	Graduate and Undergraduate Students	Administrative	Facility Support						
<b>1.0 Program Management</b>											
1.1 Director's Office											
1.3 Business Services											
<b>2.0 Facilities</b>					Low						
2.1 Observatory Facilities					Low						
<b>3.0 Primary Scientific Hardware</b>			\$820K			\$12,500K		\$1,230K			\$23,480K
3.1 Telescope		\$5000K									
3.2 Scientific Instrument 1						\$980K		\$332K			
3.3 Scientific Instrument 2											
3.4 Implementation			\$150K								
3.5 Community Sci Program			\$100K								
<b>4.0 Data Management and Computing</b>		\$10,200K						\$1,500K			\$15,300K
4.1 Data Management											
4.2 Computing Hardware											
4.3 Computing Software		\$590K									
<b>5.0 Systems I&amp;T and Commissioning</b>											
5.1 Systems I&T											
5.2 Commissioning											
<b>6.0 Operations</b>											
6.1 Operations and Maintenance											
6.2 Education and Outreach											

This presentation is a walk-through of a methodology to assess reasonableness and produce a scorecard like the one shown above



# Understanding the Challenge

*Costing unique scientific facilities begs “What’s reasonable?”*

- Challenges in costing unique science facilities impact reviews of reasonableness
  - *Diversity of facility and equipment types*
    - Research and understanding required from the analyst
  - *Availability of applicable data and models*
    - Performing a credible assessment requires historical data with reasonable fidelity
  - *Time constraints to prepare for and perform assessments*
    - Assessing reasonableness involves a short discovery and research phase
- Some challenges are specific to reviews of reasonableness
  - *How to capture the nuance of costing complex items while efficiently allocating time to assess all aspects*
    - Developing tailored criteria for what qualifies as reasonable that integrates different levels of analysis for comprehensive review with easily understandable results
      - *Some aspects of a review of reasonableness are as detailed as a full ICE while other aspects are more high-level analysis*
  - *How to address budget category characterization and constraints*
    - If project documentation does not contain clear traceability then time constraints and integrating levels of analyses becomes especially challenging



Very Large Array (VLA), New Mexico  
(Credit: Aerospace Photo)

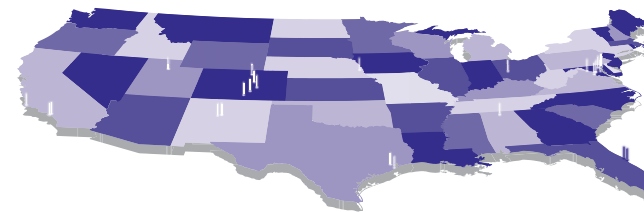
***With a strong understanding of these challenges, Aerospace analysts have developed a methodology to assess reasonableness***



# The Aerospace Corporation

## Meeting the challenges of assessing unique scientific facilities

- A Federally Funded Research and Development Center (**FFRDC**) with decades of deep institutional technical expertise, providing objective analysis and innovative solutions to the most complex problems
  - *Provides advanced scientific and engineering services for space and related high-technology systems*
- Extensive experience conducting a variety of assessments for space science projects and ground-based scientific facilities
  - *Cost and schedule analyses for **NASA** missions*
  - *Technical risk, programmatic cost assessments for **NOAA GOES** -R and -S space & ground systems*
  - *Architecture cost studies for next gen **USGS** ground system*
  - *Evaluated concepts for numerous Decadal Surveys*
  - *Independent technical and cost assessments across range of unique and complex ground facilities:*
    - Mid-scale and large facilities for **NSF**
    - Launch infrastructure and ground processing facilities for **NSS**
    - Mobile launch platforms, environmental test facilities for **NASA**
    - Material processing facilities for **NNSA**
  - *Conducted Reasonableness Reviews of large and midscale facilities for **NSF***



*"The nation's trusted partner, solving the hardest problems for the preeminent space enterprise"*



# Reasonableness Reviews

*Unique scientific facilities require detailed program plans*

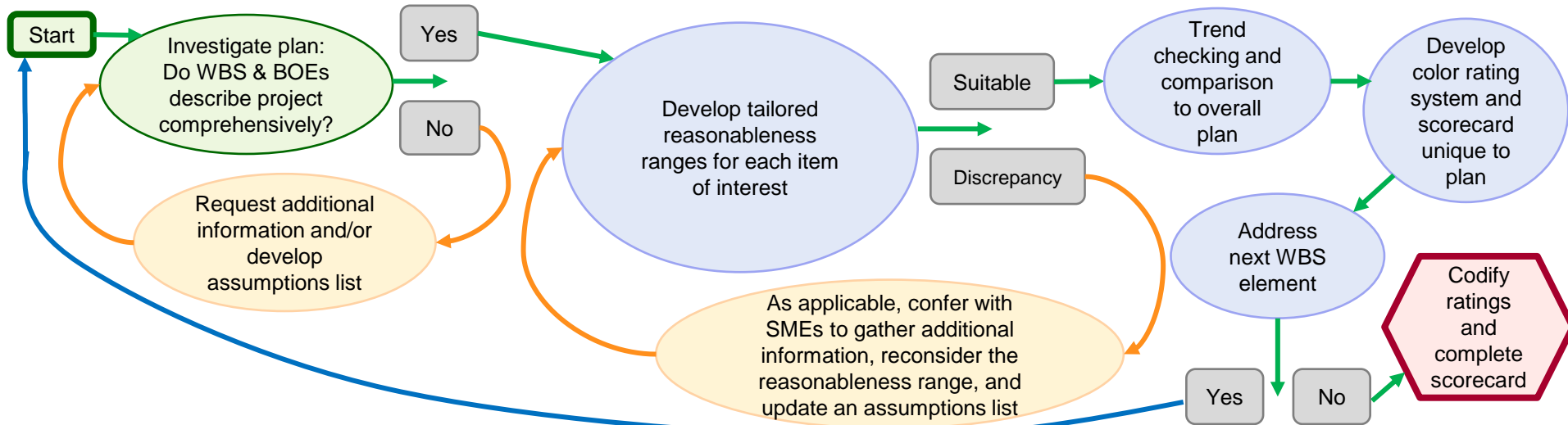
- When is a review of reasonableness applicable?
  - *When an estimate already exists for an established or non-high-risk project and must be independently reviewed or has an update in need of review, per Government Accountability Office (GAO) guidance*
    - An ICE is a bigger effort, but a Reasonableness Review can indicate if the Project Plan is sufficient and where to address problems if improvements are necessary
  - *The goals of a reasonableness review are*
    - To answer the question “Are the component aspects of the plan reasonable, and does the plan as a whole come together reasonably?”
    - Surface the “health” of the plan to program management
      - *Scorecard product summarizing strengths, weaknesses, gaps and/or risk areas*
- What information is needed to enable analysis and to assess reasonableness?
  - *What is the status quo?*
  - *What are the current plans regarding upgrading, revising, or building new?*
  - *What are the plans based on?*
  - *Sufficient data and justification*
    - The quality of Basis of Estimate (BoE) information provided is critical to enable comparison with crosschecks. Poor quality BoE or issues with traceability can cause substantial hurdles in assessing reasonableness.
  - *Seek additional expertise for fresh, unbiased & independent perspectives*



# Methodology for Assessing Cost Reasonableness

## Overview of process

- Iterative process of developing tailored reasonableness ranges and investigating lower WBS level items of interest
- ◊ – Investigation of program plan Ground Rules & Assumptions (GR&A), Bill of Materials (BOMs), BOEs, etc.
  - Is the picture complete? Are costs comprehensive to the overall plan?
- ◊ – Reasonableness range = the set of crosschecks that outline an applicable bounds of costs, from Low to High, tailored to a type of cost (budget category) and for use against specific WBS activities that contain those costs
- ◊ – Trend checking and comparing with proposal
- ◊ – Developing color rating system and score card
- ◊ – Codifying ratings with tailored scorecard GR&A, to ascribe “reasonableness”





# **Breaking it Down**

## *Developing preliminary reasonableness ranges*

- At the top level scientific facilities may be very different
  - *Commonalities often exist at lower levels of the WBS for various projects*
  - *A WBS maps key elements and allows identification of common vs. unique elements*
  - *Breaking down facilities into lower level detail makes it possible to estimate them*
- Cross-checks with historical data are a straightforward way to gauge confidence in estimates (establishment and comparison to reasonableness ranges)
  - *Can be performed for either cost, schedule, or technical parameters*
  - *Technical parameters in context with historical systems can provide a sense of how ambitious a design might be*
  - *More uncertainty in the proposed design or project plan may also mean more uncertainty in the independent cost/schedule estimates*
- Initial crosschecks come from existing metrics, factors, labor rates, etc.
  - *Access the collected knowledge of a SME or team of SMEs*
  - *Matching of what's available, what applicable, what's most analogous, etc.*





# **Iterating to Tailor Reasonableness Ranges**

## *Ranges for individual elements and wider integration*

- Program plan might outline a labor category, with implied rates – What are some comps from industry, government organizations, or academia?
  - *Bureau of Labor Statistics (BLS) rates, General Services Administration (GSA) rates, published rates at Universities, etc.*
- How would a similar set of labor compare?
- How are the labor profiles split, and then aggregated?
- How does the labor relate to Equipment purchases, technology development and integration, Operation & Maintenance (O&M), and other aspects of the plan?
- Is that an appropriate level of labor and cost, given the effort described?
- What about the Equipment itself (and other Materiel)?
- What is the role of Software and Information Technology elements, etc.?
- Portion of identified Direct Costs vs. miscellaneous Other Direct Costs?
- Consideration of subcontracts/subawards as complicating factors
- Consideration of Indirect Costs, to the extent required by the project

***There is no single definition of “reasonableness”, it is only discerned by looking closely at individual sub-elements, and aggregating to wider elements of cost***



# Example: Developing a Reasonableness Range

Analysis of plan data and initial estimates

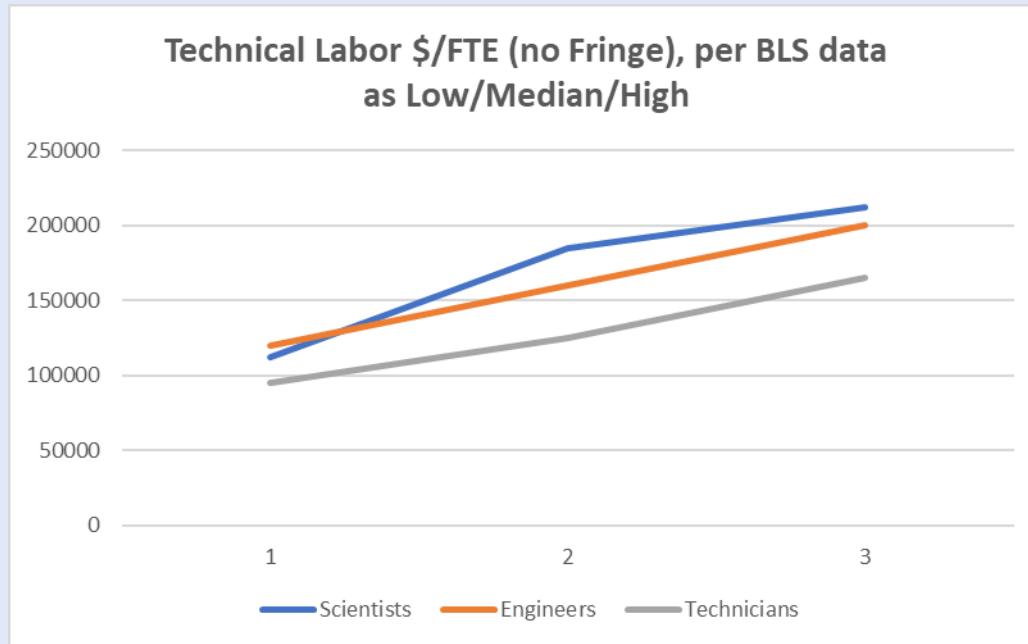
Notional data shown

Pull in relevant plan data and reorganize as needed (e.g., WBS 3.2 Scientific Instrument #1)

Technical Labor (\$ FY22)			FY 1			FY 2			Total Over 2 Years		
WBS	WBS Name	BoE	Labor Cost	FTE	\$ per FTE	Labor Cost	FTE	\$ per FTE	Labor Cost	FTE	\$ per FTE
3.2.1	Scientists	<a href="#">link here</a>	976840	5.2	\$ 187,854	1314976.92	7.0	\$ 187,854	2291816.923	12.2	\$ 187,854
3.2.2	Other	<a href="#">link here</a>	1,364,266	10.0	\$ 136,427	1,696,197	12.2	\$ 139,033	3,060,463	22.2	\$ 137,859
3.2.2.1	Engineers	<a href="#">link here</a>	727291	4.3	\$ 169,137	980997.163	5.8	\$ 169,137	1,708,288	10.1	\$ 169,137
3.2.2.2	Technicians	<a href="#">link here</a>	636975	5.7	\$ 111,750	715200	6.4	\$ 111,750	1,352,175	12.1	\$ 111,750

\*FTE = Full-Time Equivalent

Develop cross checks and determine initial reasonableness ranges



Consider where plan estimates fall within reasonableness ranges:

- Scientists fall close to median rate and well within range
- Engineers fall in similarly
- Technicians fall on low side, but still within reasonableness range

Other considerations:

- Labor mix (composition)
- Normalization of rates
- Phasing of Labor efforts
- Other, as needed

Apply scorecard ratings

	Labor		Travel
	Scientists	Technicians and	
3.2 Scientific Instrument 1			



# **Reasonableness Review “Scorecard”**

*A visual summary of the programmatic health of key plan aspects*

- Readily shows where the Project Plan has
  - *Weak or unsubstantiated costs (BOE issues)*
  - *Costs that are “out of bounds” (beyond reasonableness range crosschecked)*
  - *Risk areas, both focused ones and wider trends*
  - *Which WBS elements, and/or Budget areas are poorly planned*
  - *Opportunities for remediation, downscaling, etc.*
  
- Contains “sanity checks” of
  - *Labor vs. Materiel*
  - *Systems Engineering Management Plan, Integration and Test, and other Labor portions of costs within WBS elements*
  - *Inflation assumptions*
  - *Overall phasing (of dollars, of labor efforts, of “buys”, etc.)*
  - *Direct vs. Indirect cost ratios*
  - *Acquisition (including Development) vs. Operations and Sustainment costs*
  - *Hardware vs. Software costs, and related Information Technology/Info Systems*
  - *Transportation and Travel costs, including location factors, etc.*

**“Follow the Money” – What was already paid for? What remains? Who is paying for what, and when? How does the structure of the plan achieve its goals?**








# Scorecard Ratings (1/2)

## Rating for a low-level WBS item

- A scorecard summarizes quantitative analysis via a qualitative system, with color ratings to enable easy interpretability and use by program management
  - “How close” the project cost for a given WBS item is to its tailored reasonableness range is typically a percentage range that is specific to a given item
    - Example: “Travel costs within +/- 5% of the reasonableness range bounds are considered very reasonable (5-10% reasonable, 10-20% marginal, and exceeding 20% unreasonable)
  - Qualitative assessment of the quality of the estimate, such as whether it has the GAO characteristics of a reliable cost estimate, is also incorporated into the color ratings

### • Example color ratings for a scorecard

-  • Dark Green – Very Reasonable
  - Project information is complete comprehensive, accurate, and strongly credible for the project purposes, with cost falling well within the reasonableness range
-  • Light Green – Reasonable
  - Project information is complete comprehensive, accurate, and generally credible for the project purposes, with cost falling within the reasonableness range
-  • Yellow – Marginal
  - Project information may not be entirely complete, comprehensive, accurate, or credible for the project purpose, with cost falling near the reasonableness range
-  • Red – Unreasonable
  - Project information is insufficient, inaccurate, unreasonable, or unallowable, with cost not near the reasonableness range
-  • Gray – Not Applicable/ No Cost





# Scorecard Ratings (2/2)

## Rating for a high-level WBS item and fictional example Scorecard

- After generating the ratings of lower level WBS items (for example, WBS 1.1, 1.2, etc.), it is useful to create a rating for the higher level WBS item (WBS 1.0)

### Example criteria for high level WBS:

- If the majority of items within WBS 1.0 are a single rating then WBS 1.0 is that rating, unless:
  - If a WBS item contains 2 or more unreasonable items, then it is also unreasonable.
  - If a WBS item contains 1 unreasonable item that is not the majority, then the WBS item is marginal.
  - If the majority of items within a WBS are very reasonable but it contains 1 or more marginal items, then the WBS is reasonable.
- If there is a combination of reasonable, very reasonable, and marginal items, count all very reasonable items as reasonable when determining the majority.
- If there is a tie for the majority, the lower rating wins

	Labor					Equipment	Travel	Materials & Supplies	Information Technology	Sub-Contractors	Total Direct Costs
	Project Management	Technicians and Scientists	Graduate and Undergraduate Students	Administrative	Facility Support						
<b>1.0 Program Management</b>	Green										Green
1.1 Director's Office	Green										Green
1.3 Business Services	Green										Green
<b>2.0 Facilities</b>					Low						Green
2.1 Observatory Facilities					Low						Green
<b>3.0 Primary Scientific Hardware</b>			\$820K			\$12,500K	\$1,230K				\$23,480K
3.1 Telescope		\$5000K									Green
3.2 Scientific Instrument 1						\$980K	\$152K				Green
3.3 Scientific Instrument 2											Green
3.4 Implementation			\$150K								Green
3.5 Community Sci Program			\$100K								Green
<b>4.0 Data Management and Computing</b>		\$10,200K						\$1,500K			\$15,300K
4.1 Data Management											Green
4.2 Computing Hardware											Green
4.3 Computing Software		\$590K						\$1,500K			\$3,632K
<b>5.0 Systems I&amp;T and Commissioning</b>											Green
5.1 Systems I&T											Green
5.2 Commissioning											Green
<b>6.0 Operations</b>											Green
6.1 Operations and Maintenance											Green
6.2 Education and Outreach											Green

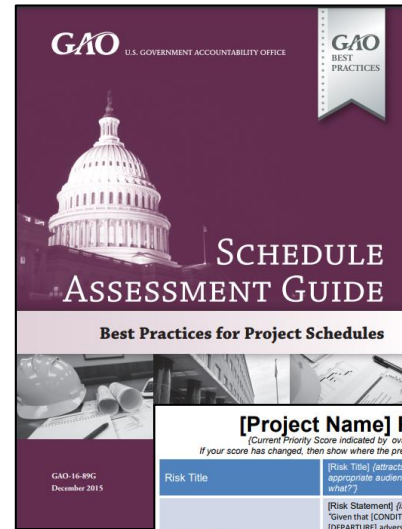
**What aspects of the plan are Green and “good to go”? What aspects are Red and considered high risk or otherwise insufficient? What aspects are Yellow (marginal)?**



# Other Uses of the Methodology

## Applications beyond assessing unique facilities costs

- The methodology of performing analysis to creating bounds of reasonableness, comparing lower level project details to these bounds, and using the comparison to build qualitative ratings can also be applied towards:
  - Assessing the reasonableness of schedule estimates
    - Can crosscheck at lower levels and assess against qualitative criteria informed by GAO characteristics of a reliable schedule
  - Evaluating cost, schedule, technical, and programmatic risks
    - Review of risk register items by independent SMEs
  - Enhancing credibility by way of sensitivity analysis (e.g. varying inflation assumptions)
- Aerospace has successfully used this methodology in these ways on various projects



Top: GAO Schedule Assessment Guide (Credit: GAO)

Middle: Risk Review Template (Credit: NASA)

Bottom: International Monetary Fund (IMF) World Economic Outlook (Credit: IMF)

**[Project Name] Risk [x] – [Internal or External]**  
(Current Priority Score indicated by oval in Risk Matrix below. [x] represent a [risk #] throughout. If your score has changed, then show where the previous score was and where the new score is as shown in the example.)

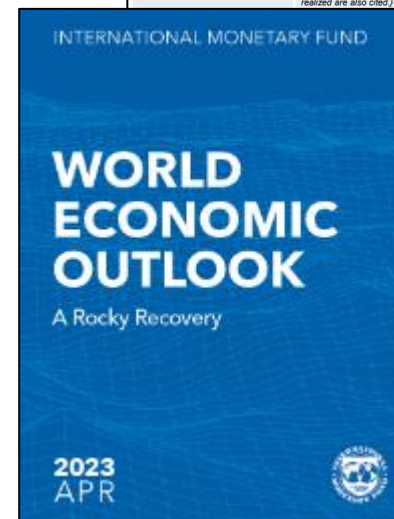
Risk Title	[Risk Title] (reflects the description and focus of the appropriate audience. It should answer the question "So what?")	L	5	4	3	2	1	
Risk Statement	[Risk Statement] (is generally written in a format of "Given that [CONDITION], there is a possibility of [DEPARTURE] adversely impacting [ASSET], thereby leading to [CONSEQUENCE]." The Risk Statement is not equivalent to the solution. The Risk Statement is written in matter-of-fact, straightforward language, avoiding the excessive use of technical terms or jargon.)	J	16	20	23	25		
		K	6	13	18	22	24	
		L	3	4	10	15	19	21
		H	2	8	11	14	17	
		O	1	5	7	9	12	
Context Statement	[Context Statement] (provides background on the Risk and should include only facts, not assumptions. The Context Statement captures the background and additional information that do not appear in the Risk Statement. The Context Statement also captures the what, when, where, how and why of the Risk by describing the circumstances, causal factors, uncertainties, and related issues. Related requirements and objectives that may be affected if the Risk is realized are also cited.)	CONSEQUENCE						

	Date
Sunrise	[Earliest date when risk may become an issue]
Sunset	[Latest date when risk may become an issue]
Impact Horizon	[Near, "Mid", or "Long"]

	Likelihood	Rationale
ed	[Current Likelihood Score]	[Likelihood Rationale] (describes the Likelihood of the Risk and why it achieved the Score it did.)
re	Was [Previous Likelihood Score]	





## Conclusion

- Aerospace analysts developed a methodology to address the questions and challenges that arise when looking at reasonableness of unique scientific facilities' costs
  - *This methodology of assessing reasonableness is applicable when an estimate already exists for an established project (not a new start) and must be independently reviewed or has an update in need of review*
  - *This methodology is an iterative process of developing tailored reasonableness ranges and systematically addressing lower WBS levels to refine estimates, which are then used to assess reasonableness of individual WBS items*
- The development of an overall 'Scorecard' can be helpful to leadership by surfacing the relative health of various aspects of the project plan, with an opportunity to revisit problem areas
- Applying the presented methodology enables a thorough assessment the reasonableness of an estimate and path for surfacing the health of the plan to program management

***Aerospace analysts will continue to refine this process and work towards further improving reasonableness assessment practices***



***Questions?***