Cost Estimation as a Function of Project Management for the International Space Station Project

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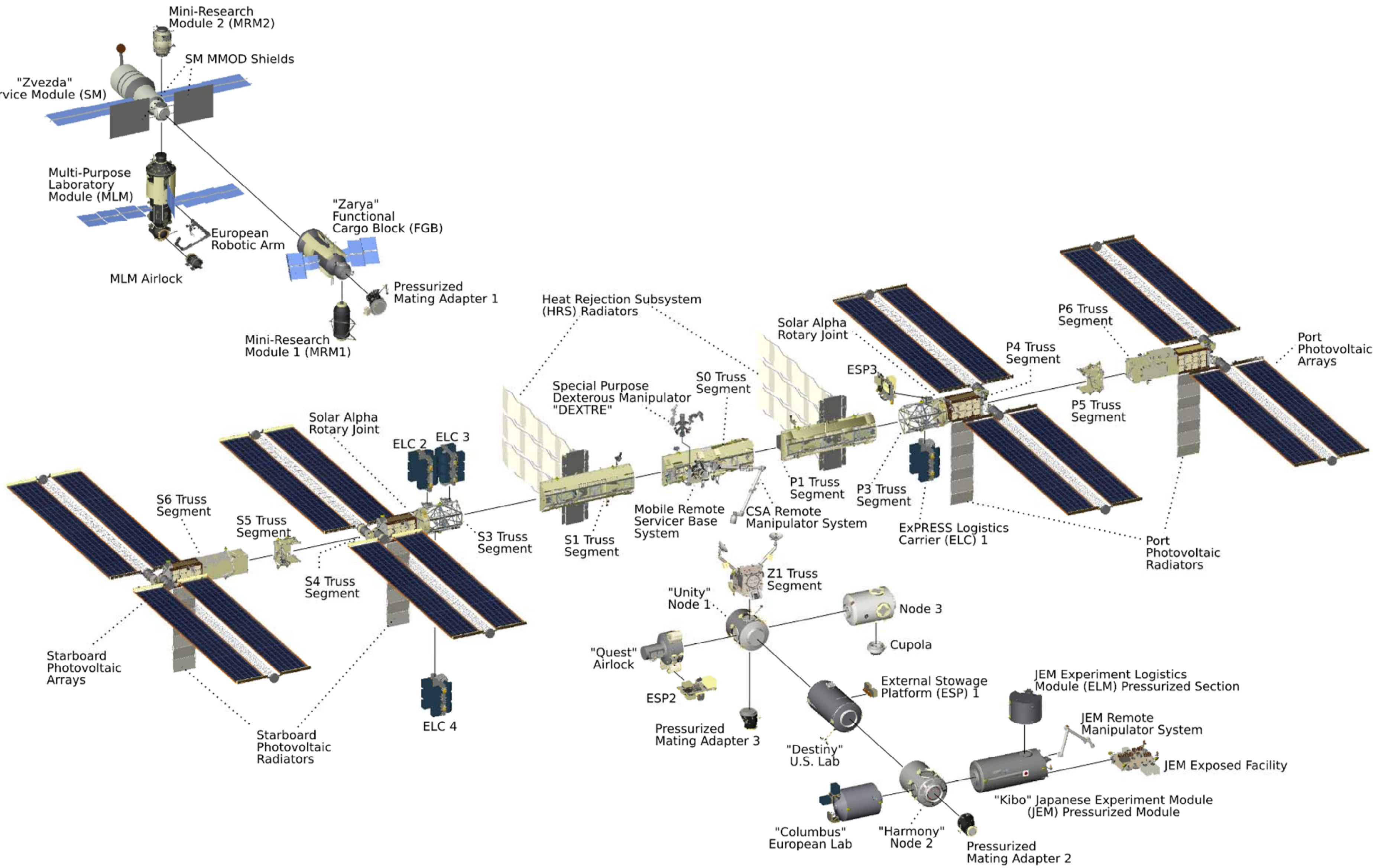
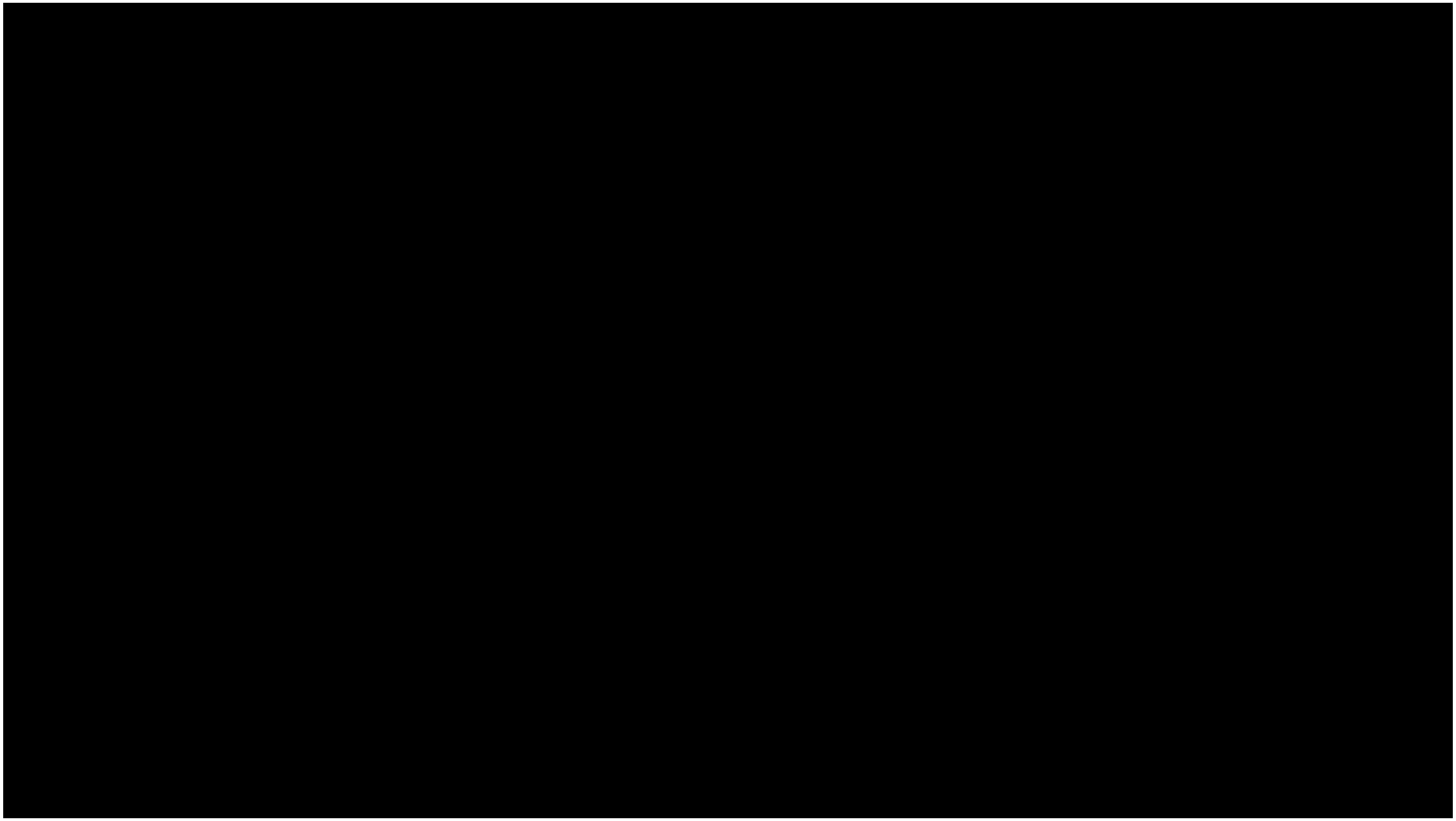
The International Space Station Program (ISS) is a complex project that has numerous countries with varying political climates and four prime contractors coming together for a common mission – to build an international laboratory in low earth orbit.



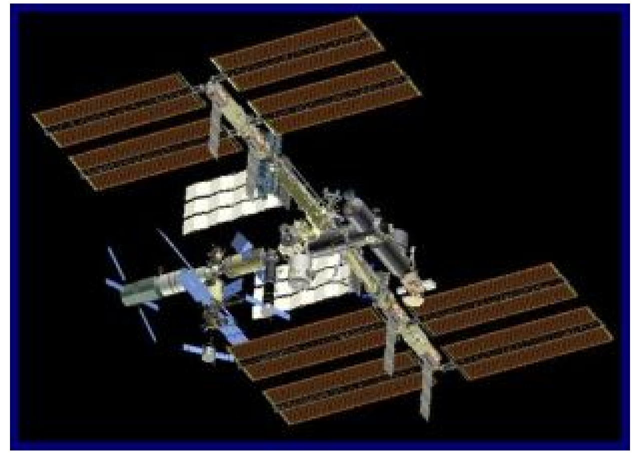
ISS Video Of Assembly



More Interesting International Space Station Program Facts: The ISS is at 51.6 degrees, covering 90% of the world's population, 200 nautical miles (on average) above the Earth 17,500 mph, orbiting the Earth 16 times per day

Post 10A Configuration

Date	Nov. 5, 2007
Length	243 ft.
Width	308 ft.
Mass	539,212 lbs.
Habitable Volume	TBD
Pressurized Volume	17,216 cubic ft.
USOS Power Generation	6 solar arrays = 63 kW



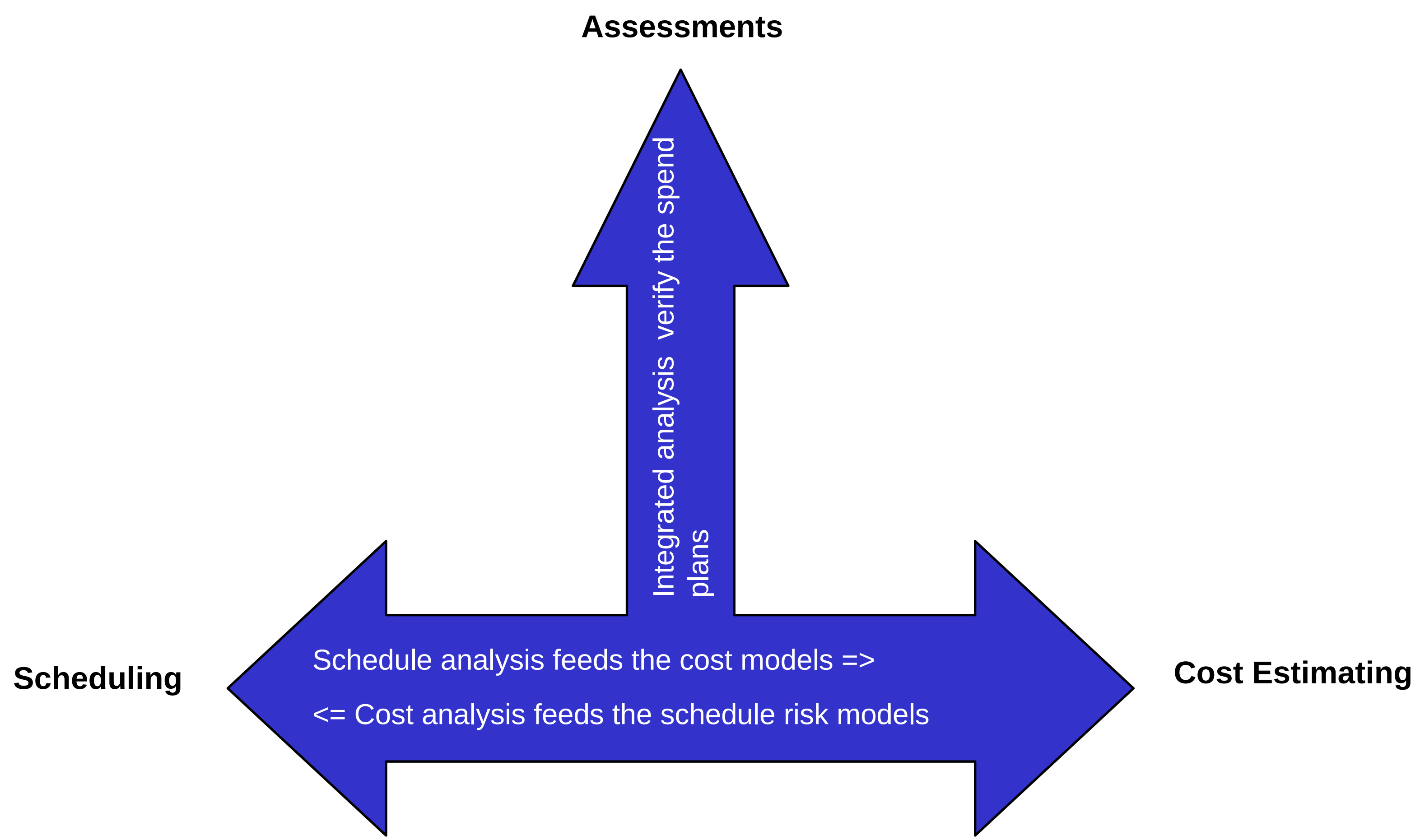
Assembly Complete

Date	July 2010
Length	243 ft.
Width	356 ft.
Mass	852,765 lbs.
Habitable Volume	TBD
Pressurized Volume	32,335 cubic ft.
USOS Power Generation	8 solar arrays = 84 kW

Since 2001, the ISS PP&C Office has been actively using project controls to help contain costs, provide trade study inputs, and help managers make decisions in terms of costs, schedule and technical attributes

- **Cost estimation is part of the overall project management function within the Program Planning and Control Office**
  - **This allows estimators to be on par with engineers**
  - **Cost estimates can be non-advocate of technical agendas**
  - **Provides a checks and balances process**

All of the Assessments, Cost Estimating and Schedules (ACES) team members have various tool certifications – including SEER-H™ and SEER-SEM™ – most are also cross-trained in the other disciplines



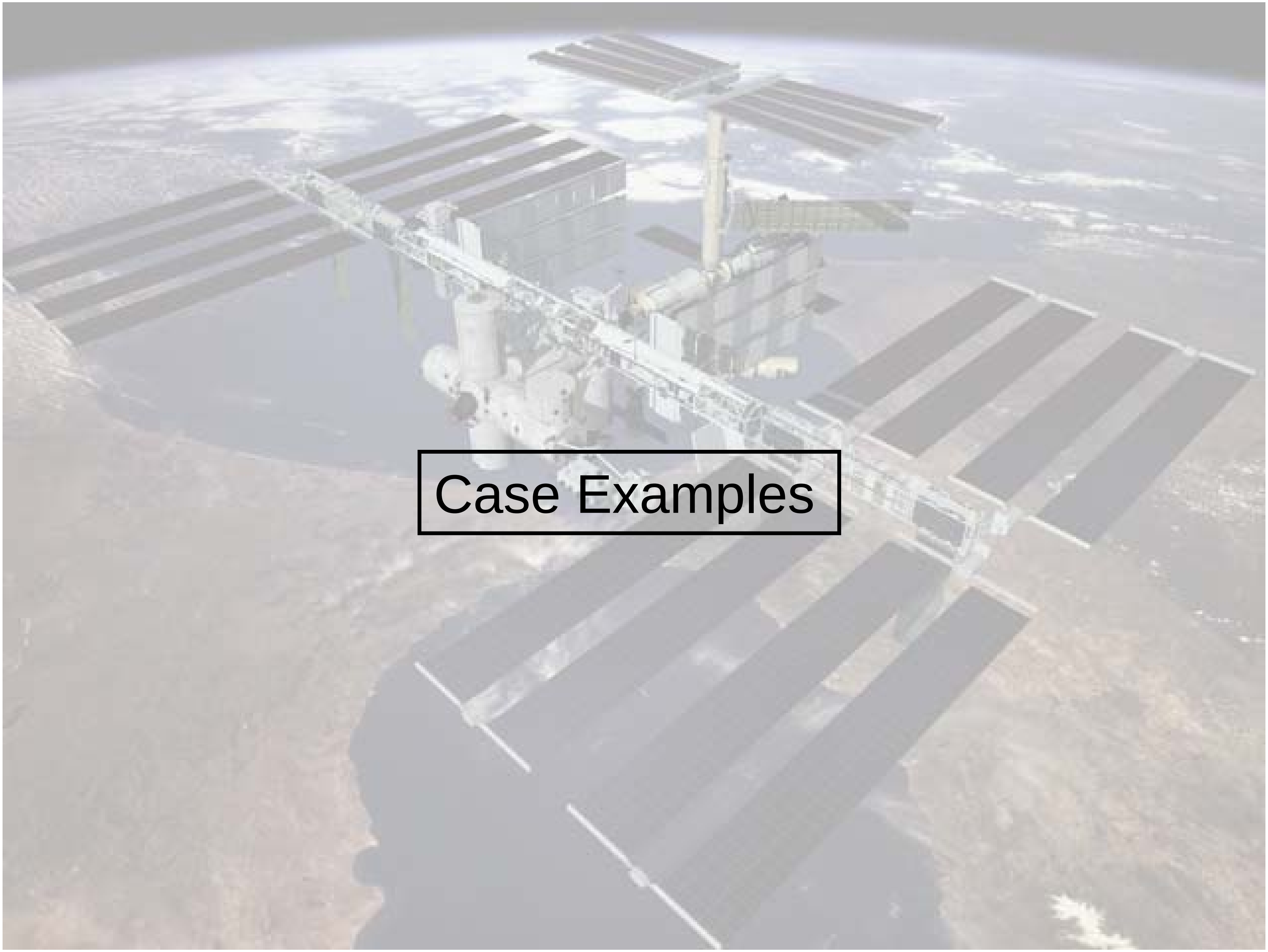
The cost estimators are responsible for a variety of cost analysis. With the volume of changes in a dynamic environment such as ISS, parametric tools allow us to create estimates with high fidelity in short time frames

Cost Estimating	Assessments	Schedules
▪ Cost Estimates of Baseline Changes ▪ Cost Estimates of Threats ▪ Quantitative Risk Assessment of Threats/Budget ▪ Documentation of Processes ▪ Utilization of Cost Models ▪ Government Estimates for Procurements ▪ Cost/Benefit Analysis	▪ Early Warning System – Monthly and Quarterly Reports ▪ Earned Value Management Analysis ▪ Program Metrics ▪ Program Performance Measurement System ▪ Assessments of budgets, contracting and processes	▪ Integrated Schedules ▪ Cost/Schedule Risk Analysis ▪ Schedule Assessments

The questions often asked from the ISS engineering community include model validity and project need

- In order to provide insight into the validity,
  - NASA HQ and Galorath have provided jumpstarts with the cost estimators and engineers to promote understanding of tool functions
  - ACES has calibrated their models using actuals examples include:
    - Shuttle Station Power Transfer System (SSPTS)
    - Express Logistics Carrier (ELC)

- How are the estimates used for a diverse program in the operational phase?
  - Program management decisions
    - Cost estimate ‘should costs’ in comparison to contractor cost ROMs
    - Trade study/what if analysis
    - Estimating baseline changes
  - Provide procurement insight for negotiations, examples include
    - Russian-built Waste and Hygiene Compartment (WHC)
    - S-Band Antenna Sub-Assembly (SASA)
    - Androgynous Peripheral Assembly System (APAS) trade study

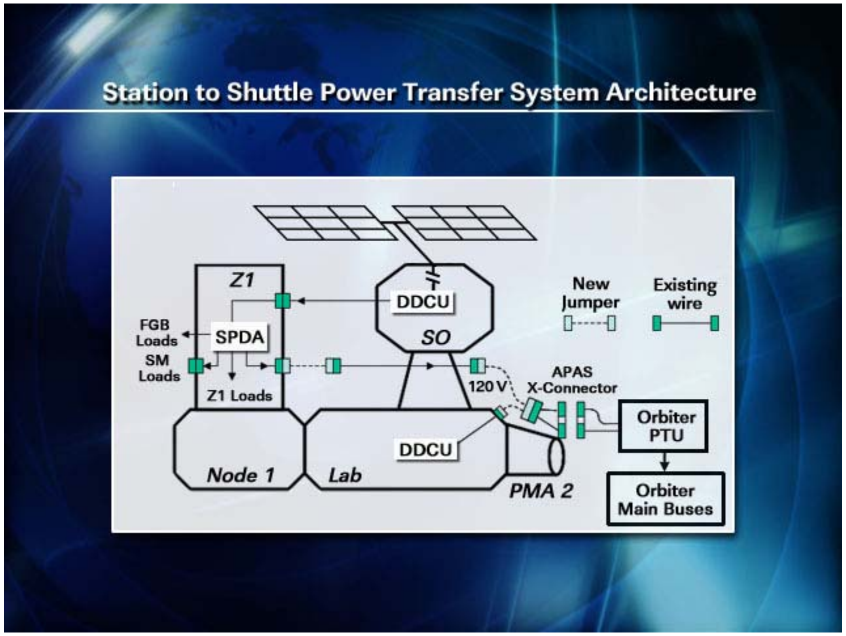


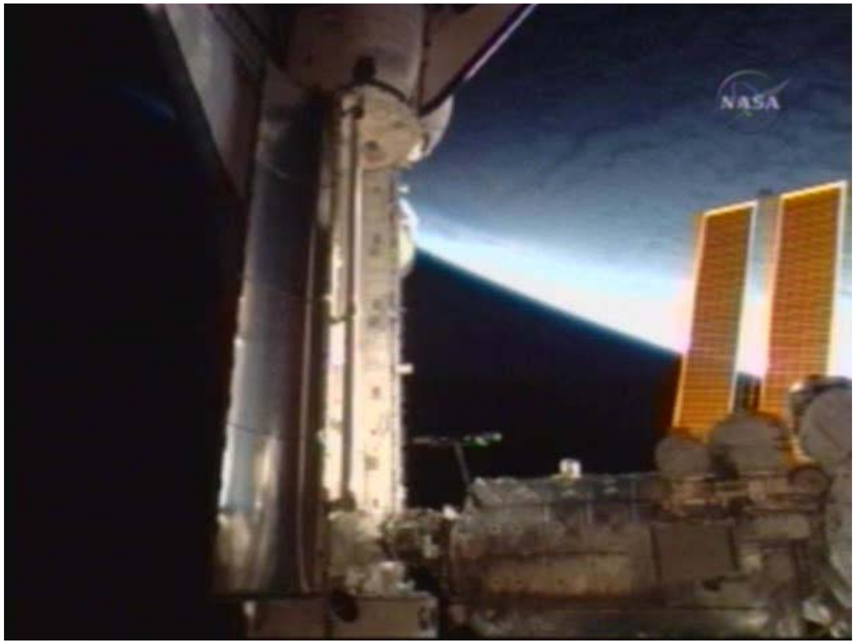
Case Examples

Case Example 1

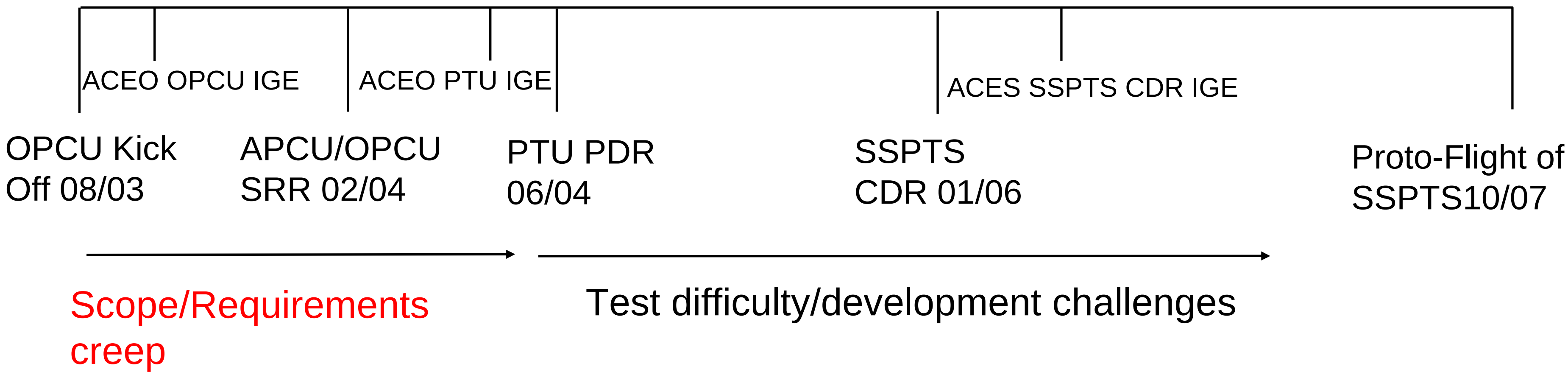
Shuttle-Station Power Transfer System (SSPTS) Cost Study Background

- From 2003 - 2007, the ACES team has been updating and calibrating a SEER H model for SSPTS, a recently completed large ($100M+) NASA development effort
- An estimate was created based on all of the available data
- A comparison was made between the point estimate and the actual cost
- Analysis of the difference between the estimated outcome and the actual outcome has been used for other estimates





The SSPTS cost estimate evolved as the program changed. SEER H was used to validate all costs and calibrated at the various phases of the estimates



		2004	2005	2006	2007	2008	Total
9/2003	POP 2003 OPCU	*1%*	*16%*	*24%*	*7%*		*48%*
	OPCU ACEO Estimate	*3%*	*15%*	*24%*	*6%*		*48%*
5/2004	Power Transfer Unit (PTU)	*29%*	*46%*	*33%*	*0%*		*109%*
	ACEO Cost Estimate	*25%*	*34%*	*25%*	*8%*		*93%*
7/2006	SSPTS Budget	*29%*	*46%*	*33%*	*0%*		*109%*
	ACES Estimate to Complete	*41%*	*44%*	*11%*	*0%*		*96%*
	SEER-H CDR calibrated	*40%*	*42%*	*8%*	*0%*		*91%*
	Non Prime Actuals	*0%*	*2%*	*3%*	*0%*		*5%*
12/2007	Actual Cost	*24%*	*36%*	*29%*	*12%*	*0%*	*100%*
	Prime	*23%*	*34%*	*26%*	*12%*	*0%*	*95%*
	Non-Prime	*0%*	*2%*	*3%*	*0%*	*0%*	*5%*

Percentages are relative to the actual costs.

System requirements review (SRR) level of detail estimates proved to be within 7% of actual costs. By SSPTS CDR Estimating Breakdown Structure grew significantly from the SRR due to a higher level of detail available

Estimating Breakdown Structure as of PDR

1	Project
1.1	Rollup
1.1.1	Hardware
1.1.2	Hardware
1.1.3	Hardware
1.2	Rollup
1.2.1	Electronics
1.2.1.1	Hardware
1.2.1.2	Hardware
1.2.1.3	Hardware
1.2.1.4	Hardware
1.2.1.4.1	Hardware
1.2.1.4.2	Electronics
1.2.1.4.3	Electronics
1.2.1.4.4	Electronics
1.2.1.4.5	Electronics
1.2.2	Electronics
1.2.2.1	Electronics
1.2.2.2	Hardware
1.2.2.3	Hardware
1.2.2.4	Hardware
1.2.2.4.3	Hardware
1.2.2.4.4	Electronics
1.2.2.4.5	Electronics
1.2.2.4.6	Electronics
1.2.3	Electronics
1.2.4	Electronics
1.3	Rollup
1.3.1	Hardware
1.4	Rollup
1.4.1	Hardware
1.4.2	Hardware
1.4.3	Hardware
1.5	Rollup
1.5.1	Hardware

Estimating Breakdown Structure as of CDR

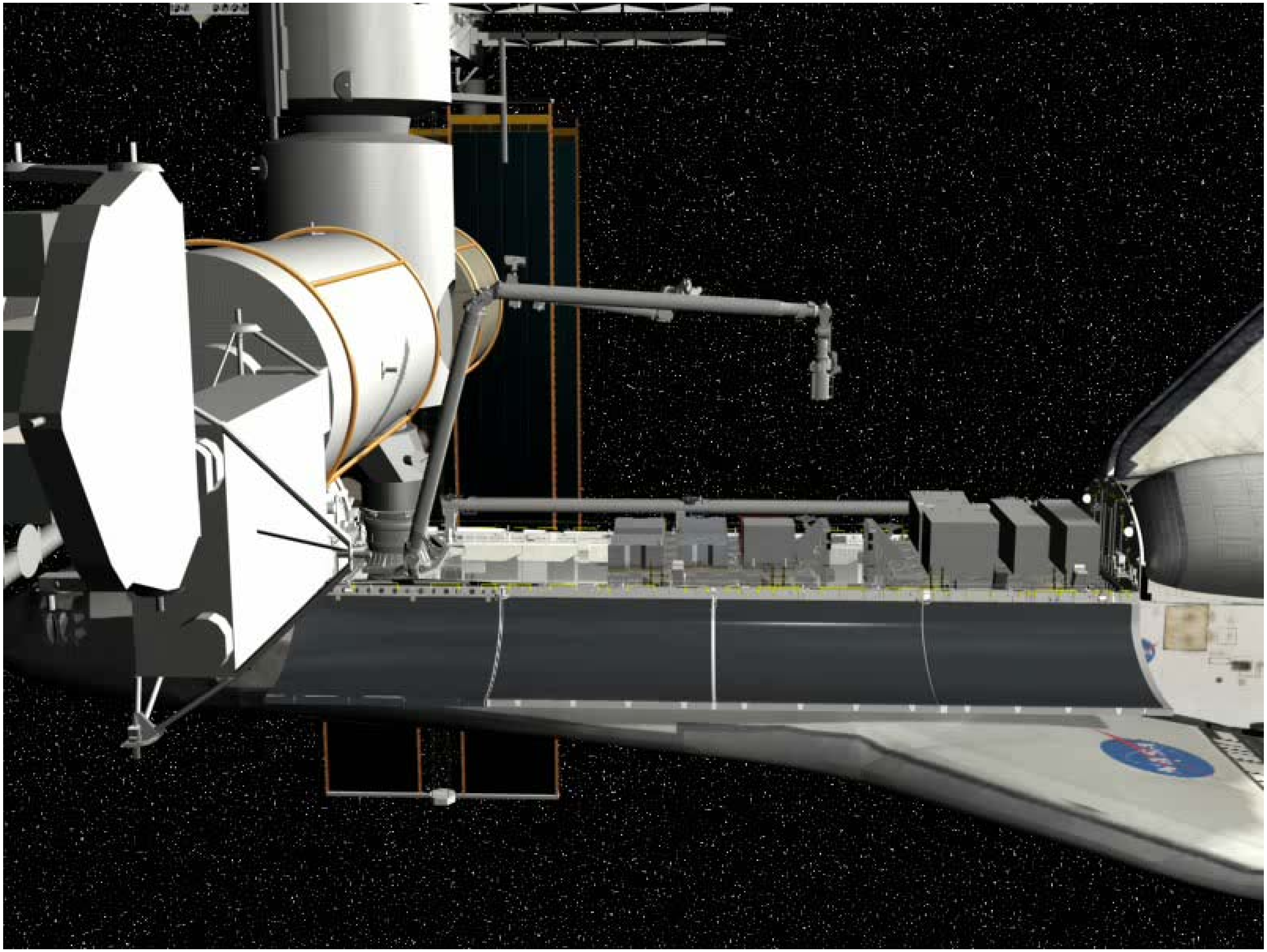
1	PROJECT
1.1	ROLLUP
1.1.1	ROLLUP
1.1.1.1	Mechanical/Structural
1.1.1.2	Mechanical/Structural
1.1.1.3	Mechan
1.1.1.4	Mechan
1.1.1.5	Mechan
1.1.1.6	Mechan
1.1.1.7	Mechan
1.1.1.8	Mechan
1.1.1.9	Mechan
1.1.2	ROLLUI
1.1.2.1	Mechan
1.1.2.2	ROLLUI
1.1.2.2.1	Mechan
1.1.2.2.2	Mechan
1.1.2.2.3	Electron
1.1.2.2.4	Electron
1.1.2.2.5	Electron
1.1.2.2.6	Electron
1.1.2.2.7	Electron
1.1.2.2.8	Electron
1.1.2.2.9	Electron
1.1.2.3	ROLLUI
1.1.2.3.1	Mechan
1.1.2.3.2	Mechan
1.1.2.3.3	Electron
1.1.2.3.4	Electron
1.1.2.3.5	Electron
1.1.2.3.6	Electron
1.1.2.3.7	Electron
1.1.2.3.8	Electron
1.1.2.4	Electron
1.1.2.5	Electron
1.1.2.6	Electron

1.1.3	ROLLUP
1.1.3.1	Mechanical/Structural
1.1.3.2	Mechanical/Structural
1.1.3.3	Mechanical/Structural
1.1.3.4	Mechanical/Structural
1.1.3.5	Mechanical/Structural
1.1.3.6	Mechanical/Structural
1.1.4	ROLLUP
1.1.4.1	Mechanical/Structural
1.1.4.2	Electronics
1.1.4.3	Electronics
1.1.4.4	Electronics
1.1.4.5	Electronics
1.2	ROLLUP
1.2.1	Mechanical/Structural
1.2.2	Addin
1.2.3	Addin
1.2.4	ROLLUP
1.2.4.1	Mechanical/Structural
1.2.4.2	Mechanical/Structural
1.2.4.3	Mechanical/Structural
1.2.4.4	Mechanical/Structural
1.2.4.5	Mechanical/Structural
1.2.4.6	Mechanical/Structural
1.2.4.7	Mechanical/Structural
1.2.4.8	Mechanical/Structural
1.2.5	ROLLUP
1.2.5.1	Mechanical/Structural
1.2.5.2	Mechanical/Structural
1.2.5.3	Mechanical/Structural
1.2.5.4	Mechanical/Structural
1.2.5.5	Mechanical/Structural
1.2.5.6	Mechanical/Structural
1.2.5.7	Mechanical/Structural
1.2.5.8	Mechanical/Structural
1.2.6	ROLLUP
1.2.6.6	Mechanical/Structural
1.2.6.7	Mechanical/Structural
1.2.6.8	Mechanical/Structural

Estimates at this level with CDR fidelity detail are within 5% of actual costs

Case Example 2

Express Logistics Carrier (ELC) Cost Study Background



ELC Project Estimate Overview

Carrier Trade Studies 7/05

ELC PDR 06/06

ELC Avionics CDR 01/06

ELC Structural CDR 05/07

ELC Avionics Delta CDR 02/08

Flight of ELC 1

9/2009

Schedule Challenges

Major redesign of avionics

Major reduction of Mass

Iteration 1 – Based on Trade Study – doesn't include phase II of the project

Iteration 2 –

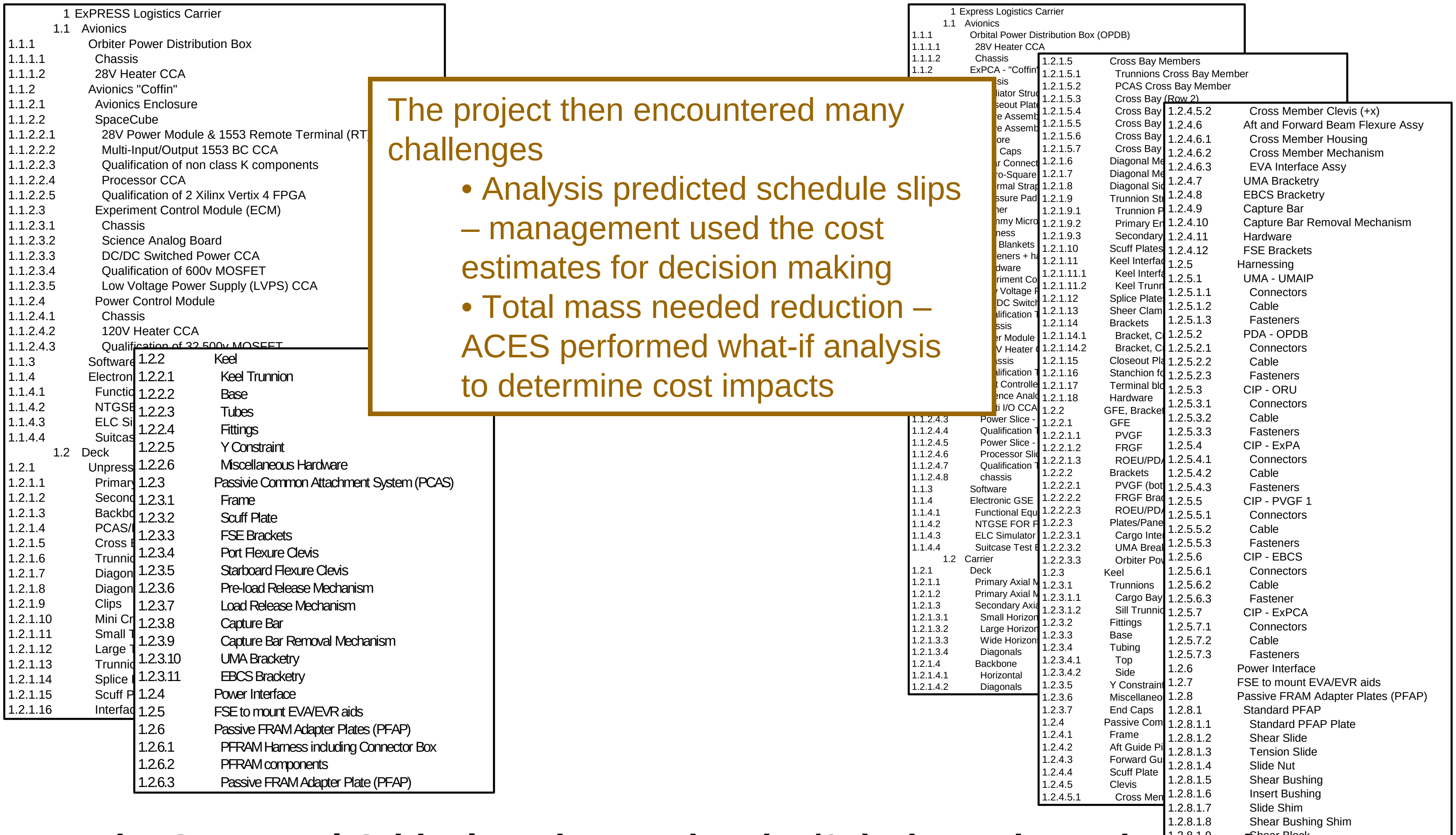
18-20 % cost growth due to schedule challenges, addition of phase II and risks

Iteration 3 – close to iteration 2 incorporates major redesign

Iteration 4 – Similar to iteration 3 incorporates major mass reductions

Current Project Manager's EAC - Falls in the range on iteration 4

At the trade study phase, the estimate was modeled at the system level with 1-10 work elements. By PDR, the estimate was re-modeled to a subsystem level growing from about 10 to 72 work elements



The project then encountered many challenges

- Analysis predicted schedule slips – management used the cost estimates for decision making
- Total mass needed reduction – ACES performed what-if analysis to determine cost impacts

At the Structural Critical Design Review (11/07), the estimate iterated to a component level of detail (180+ components) and incorporated some critical design changes such as weight reduction - a major driver of parametric estimating

In summary…

…Complex programs face intense challenges

…There is an importance in practicing stringent project controls within PM

…Tools such as SEER H and SEER SEM are an important part of cost analysis

- Enable independent cost estimates for informed decision making
- Provide auditable, defensible and well documented cost estimates
- Help to ensure best practices for users

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