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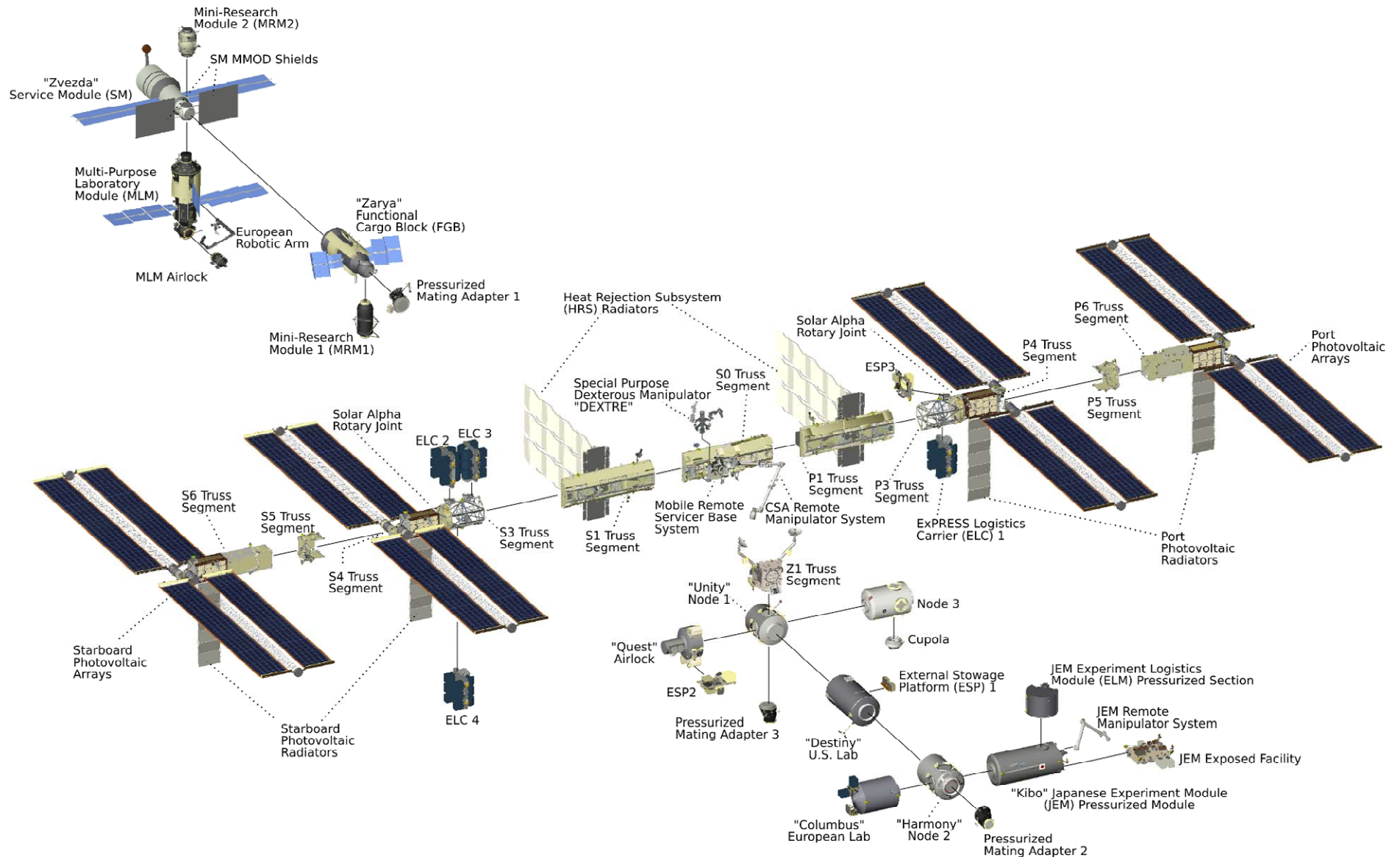
# **Cost Estimation as a Function of Project Management for the International Space Station Project**

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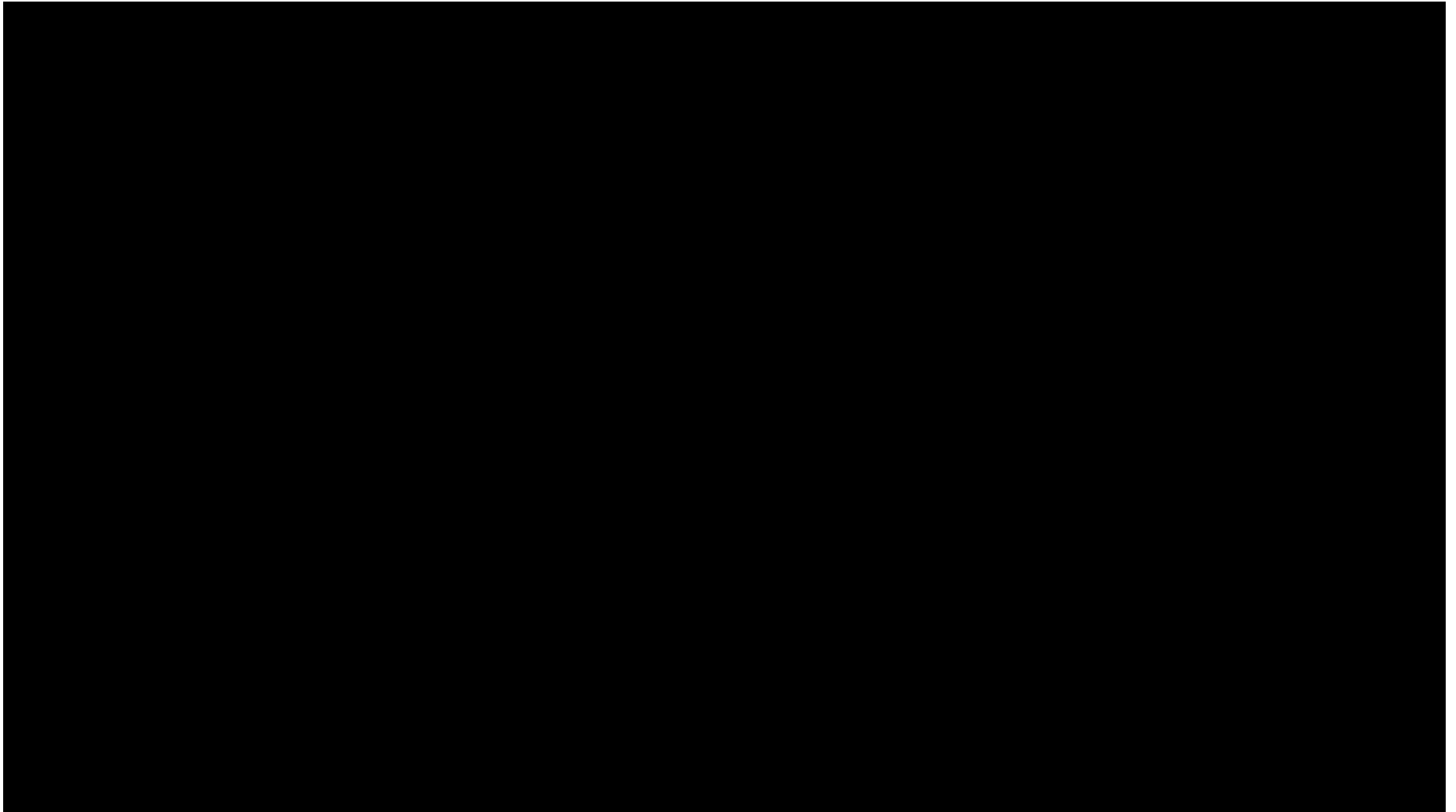
*Krista Stroh*

*04/9/08*

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.



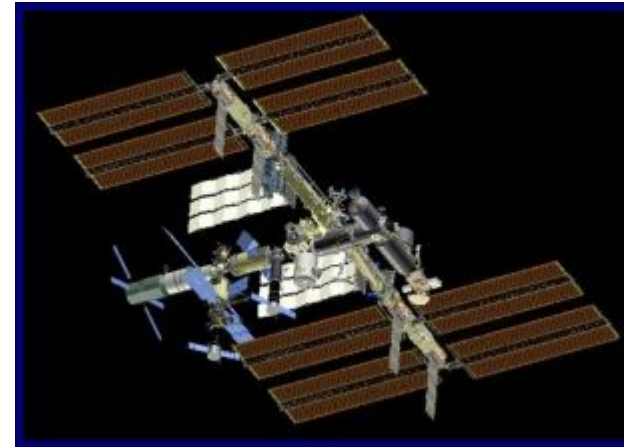
## ISS Video Of Assembly



**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**



**Assembly Complete**

<b>Date</b>	Nov. 5, 2007
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<b>Length</b>	243 ft.
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<b>Width</b>	308 ft.
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<b>Mass</b>	539,212 lbs.
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<b>Habitable Volume</b>	TBD
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<b>Pressurized Volume</b>	17,216 cubic ft.
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<b>USOS Power Generation</b>	6 solar arrays = 63 kW
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<b>Date</b>	July 2010
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<b>Length</b>	243 ft.
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<b>Width</b>	356 ft.
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<b>Mass</b>	852,765 lbs.
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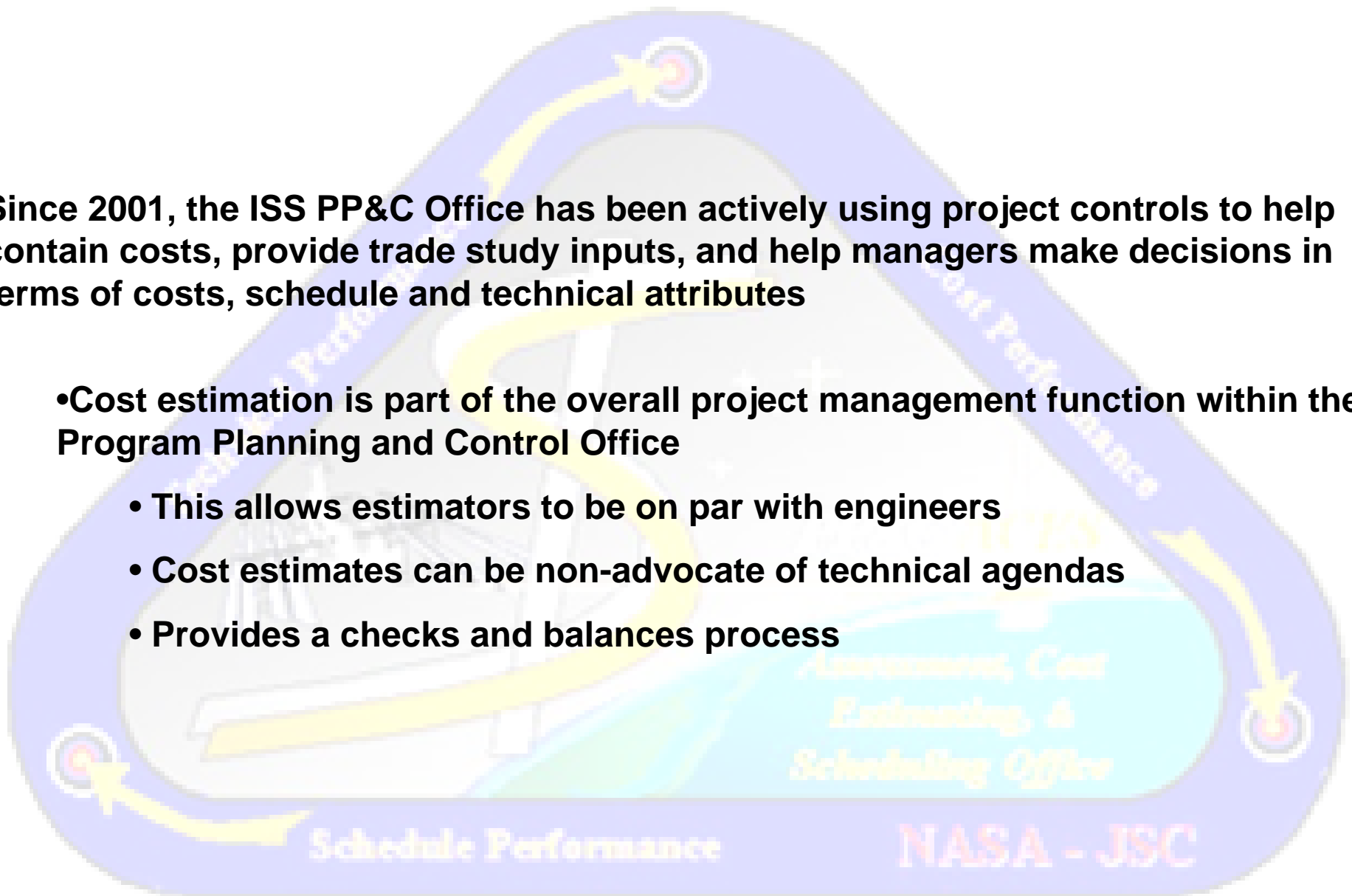
<b>Habitable Volume</b>	TBD
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<b>Pressurized Volume</b>	32,335 cubic ft.
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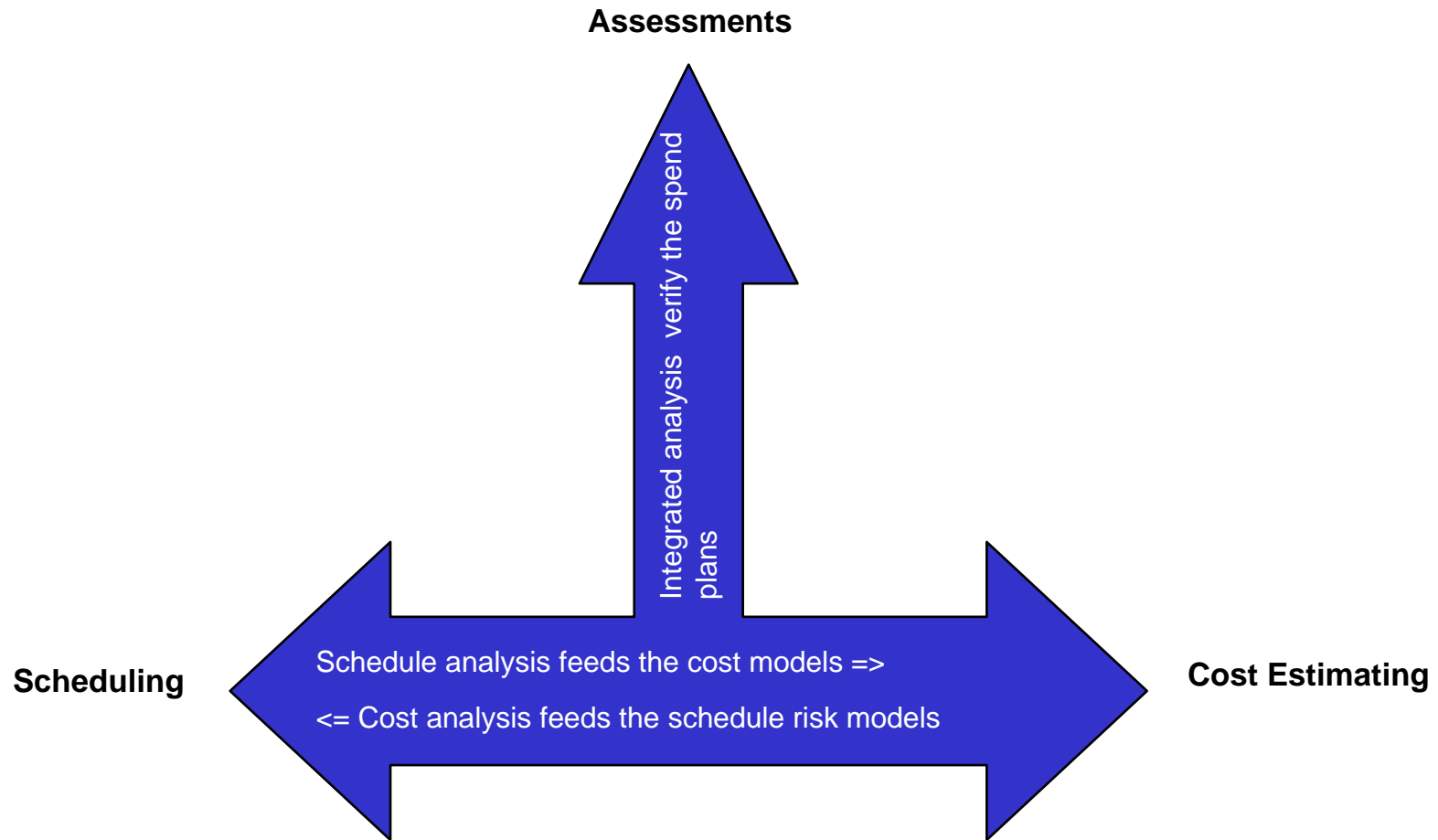
<b>USOS Power Generation</b>	8 solar arrays = 84 kW
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Since 2001, the ISS PP&C Office has been actively using project controls to help contain costs, provide trade study inputs, and help managers make decisions in terms of costs, schedule and technical 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
<ul style="list-style-type: none"> <li>▪ Cost Estimates of Baseline Changes</li> <li>▪ Cost Estimates of Threats</li> <li>▪ Quantitative Risk Assessment of Threats/Budget</li> <li>▪ Documentation of Processes</li> <li>▪ Utilization of Cost Models</li> <li>▪ Government Estimates for Procurements</li> <li>▪ Cost/Benefit Analysis</li> </ul>	<ul style="list-style-type: none"> <li>▪ Early Warning System – Monthly and Quarterly Reports</li> <li>▪ Earned Value Management Analysis</li> <li>▪ Program Metrics</li> <li>▪ Program Performance Measurement System</li> <li>▪ Assessments of budgets, contracting and processes</li> </ul>	<ul style="list-style-type: none"> <li>▪ Integrated Schedules</li> <li>▪ Cost/Schedule Risk Analysis</li> <li>▪ Schedule Assessments</li> </ul>

## **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**

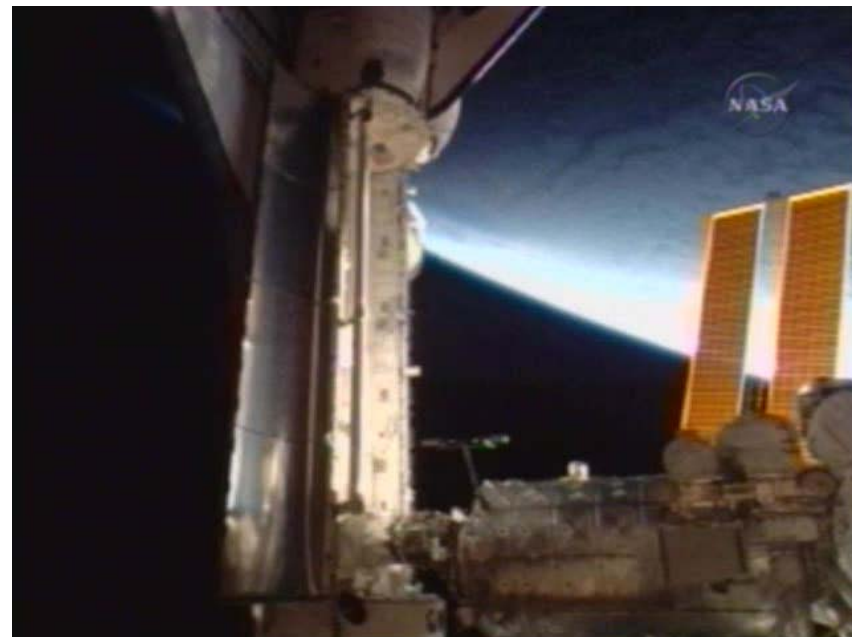
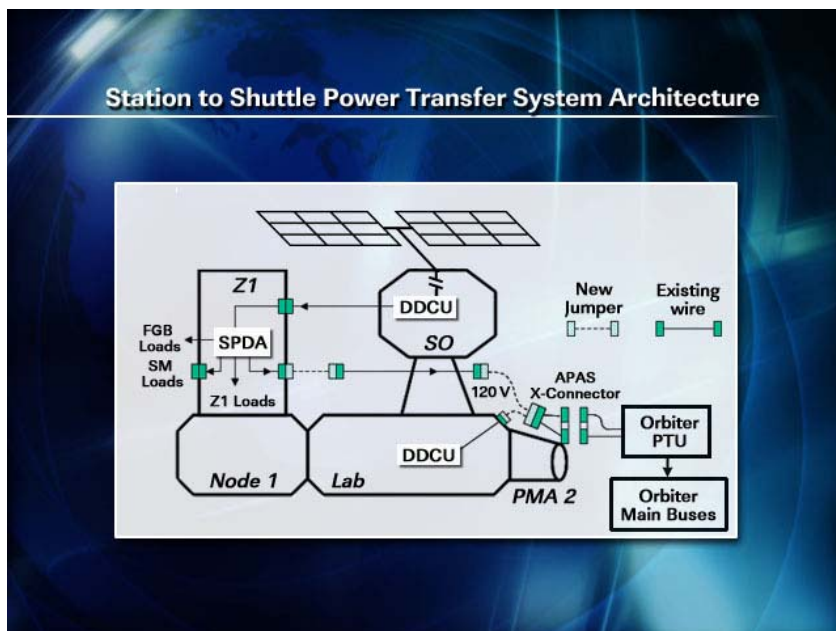
The image shows the International Space Station (ISS) in orbit above the Earth. The station's complex structure, including multiple modules and large solar panel arrays, is clearly visible against the blue and white clouds of the planet. The perspective is from a high angle, looking down at the station as it orbits. A semi-transparent black box with a white border is centered over the station, containing the text "Case Examples".

# Case Examples

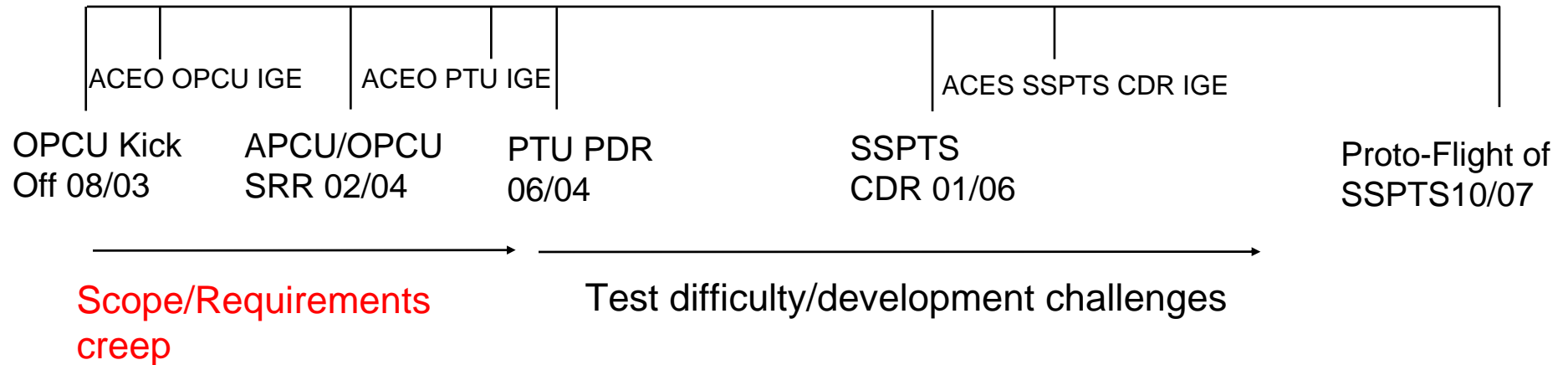
## Case Example 1

### 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%
<hr/>							
5/2004	Power Transfer Unit (PTU)	29%	46%	33%	0%		109%
	ACEO Cost Estimate	25%	34%	25%	8%		93%
<hr/>							
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%
<hr/>							
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	ROLLUP
1.1.2.1	Mechan
1.1.2.2	ROLLUP
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	ROLLUP
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

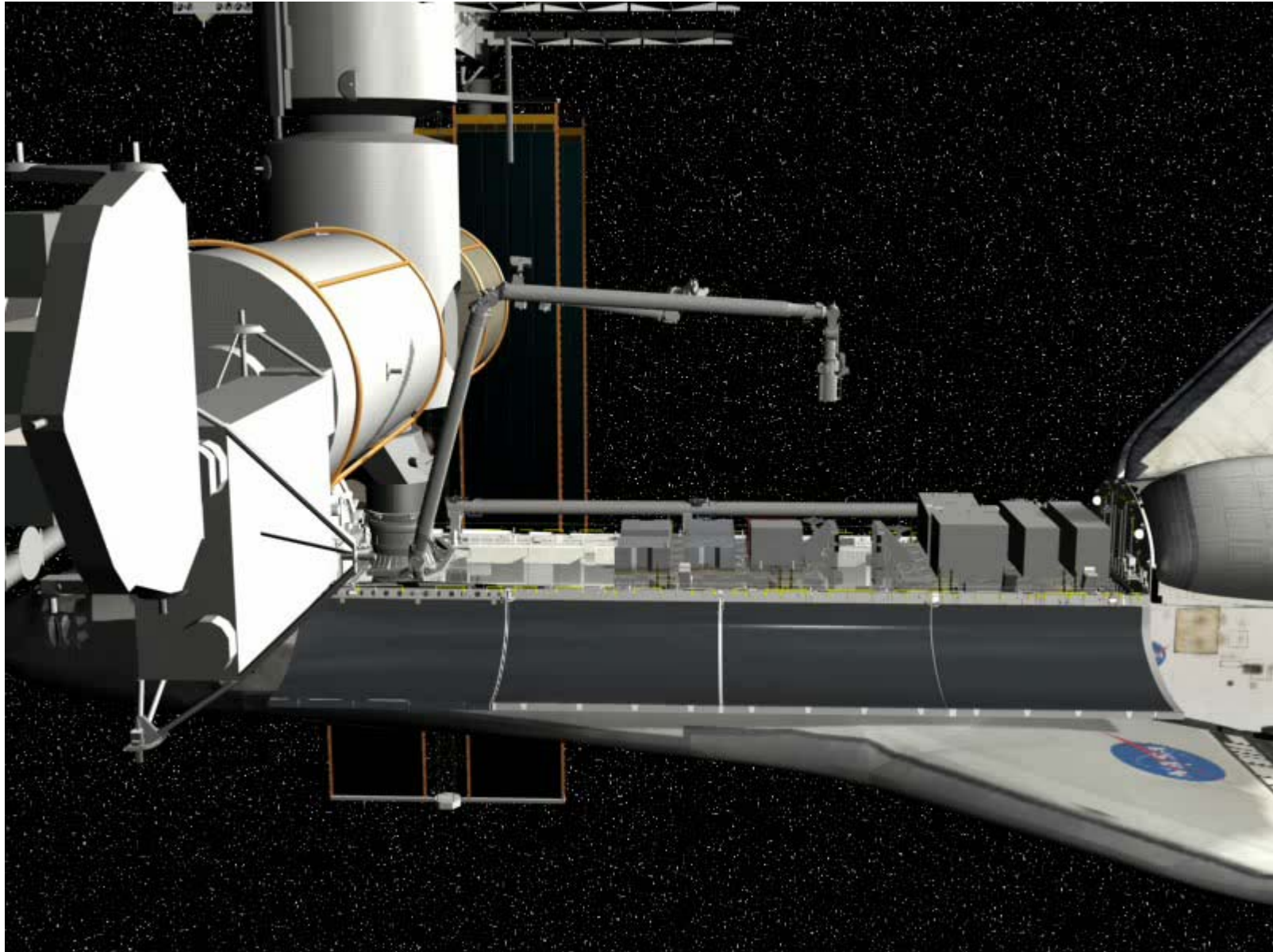
1.1.3	ROLLUP
1.1.3.1	Mechanical/Structural
1.1.3.2	Mechanical/Structural
1.1.3.3	Mechanical/Structural
1.1.3.4	Mechanical/Structural
1.1.3.5	Mechanical/Structural
1.1.3.6	Mechanical/Structural
1.1.4	ROLLUP
1.1.4.1	Mechanical/Structural
1.1.4.2	Electronics
1.1.4.3	Electronics
1.1.4.4	Electronics
1.1.4.5	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

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

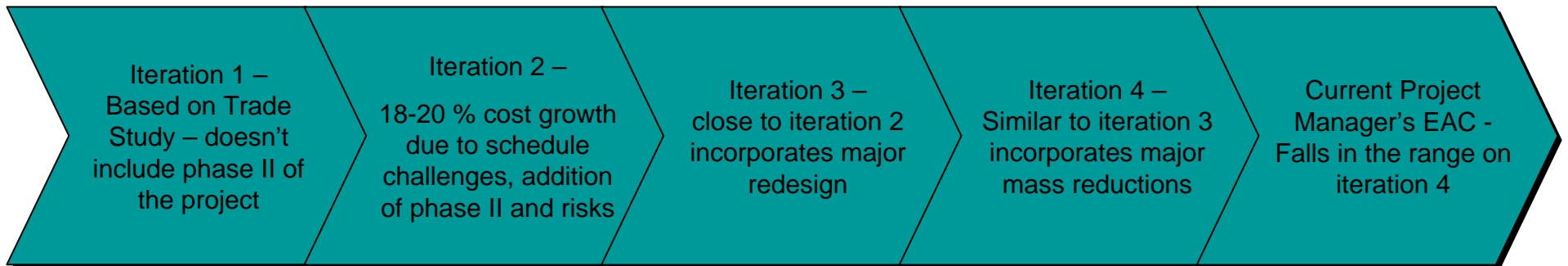
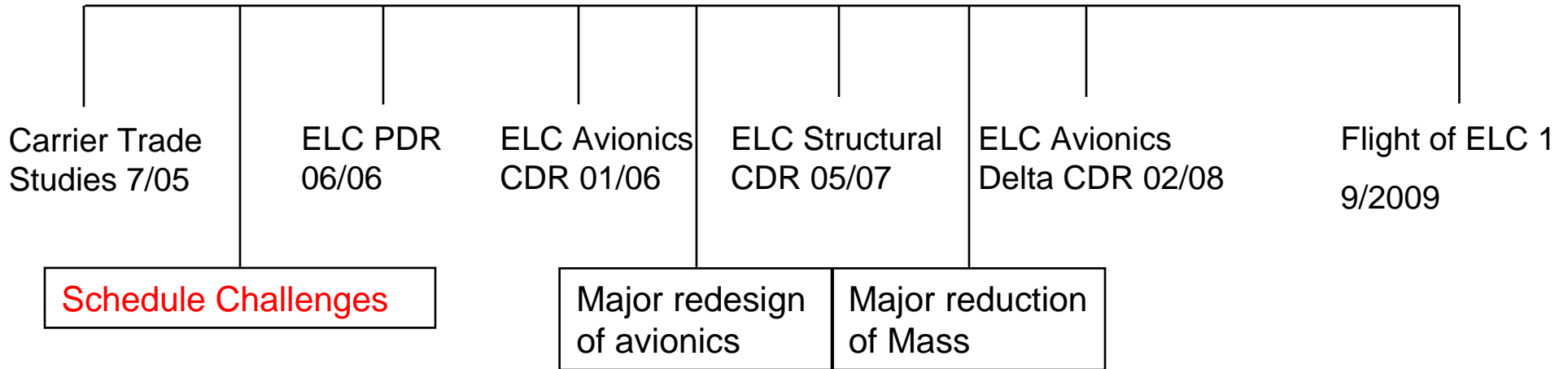
1.2.6.6	Mechanical/Structural
1.2.6.7	Mechanical/Structural
1.2.6.8	Mechanical/Structural

## Case Example 2

### Express Logistics Carrier (ELC) Cost Study Background



# ELC Project Estimate Overview



**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**

1	EXPRESS Logistics Carrier
1.1	Avionics
1.1.1	Orbiter Power Distribution Box
1.1.1.1	Chassis
1.1.1.2	28V Heater CCA
1.1.2	Avionics "Coffin"
1.1.2.1	Avionics Enclosure
1.1.2.2	SpaceCube
1.1.2.2.1	28V Power Module & 1553 Remote Terminal (RT)
1.1.2.2.2	Multi-Input/Output 1553 BC CCA
1.1.2.2.3	Qualification of non class K components
1.1.2.2.4	Processor CCA
1.1.2.2.5	Qualification of 2 Xilinx Vertix 4 FPGA
1.1.2.3	Experiment Control Module (ECM)
1.1.2.3.1	Chassis
1.1.2.3.2	Science Analog Board
1.1.2.3.3	DC/DC Switched Power CCA
1.1.2.3.4	Qualification of 600V MOSFET
1.1.2.3.5	Low Voltage Power Supply (LVPS) CCA
1.1.2.4	Power Control Module
1.1.2.4.1	Chassis
1.1.2.4.2	120V Heater CCA
1.1.2.4.3	Qualification of 22,500v MOSFET
1.1.3	Software
1.1.4	Electronics
1.1.4.1	Functional
1.1.4.2	NTGSE
1.1.4.3	ELC Sim
1.1.4.4	Suitcase
1.2	Deck
1.2.1	Unpress
1.2.1.1	Primary
1.2.1.2	Secondary
1.2.1.3	Backbone
1.2.1.4	PCAS/
1.2.1.5	Cross Bay
1.2.1.6	Trunnion
1.2.1.7	Diagonal
1.2.1.8	Diagonal
1.2.1.9	Clips
1.2.1.10	Mini Cr
1.2.1.11	Small T
1.2.1.12	Large T
1.2.1.13	Trunnion
1.2.1.14	Splice
1.2.1.15	Scuff P
1.2.1.16	Interface
1.2.2	Keel
1.2.2.1	Keel Trunnion
1.2.2.2	Base
1.2.2.3	Tubes
1.2.2.4	Fittings
1.2.2.5	Y Constraint
1.2.2.6	Miscellaneous Hardware
1.2.3	Passive Common Attachment System (PCAS)
1.2.3.1	Frame
1.2.3.2	Scuff Plate
1.2.3.3	FSE Brackets
1.2.3.4	Port Flexure Clevis
1.2.3.5	Starboard Flexure Clevis
1.2.3.6	Pre-load Release Mechanism
1.2.3.7	Load Release Mechanism
1.2.3.8	Capture Bar
1.2.3.9	Capture Bar Removal Mechanism
1.2.3.10	UMA Bracketry
1.2.3.11	EBCS Bracketry
1.2.4	Power Interface
1.2.5	FSE to mount EVA/EVR aids
1.2.6	Passive FRAM Adapter Plates (PFAP)
1.2.6.1	PFRAM Harness including Connector Box
1.2.6.2	PFRAM components
1.2.6.3	Passive FRAM Adapter Plate (PFAP)

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

1	EXPRESS Logistics Carrier	1.2.1.5	Cross Bay Members
1.1	Avionics	1.2.1.5.1	Trunnions Cross Bay Member
1.1.1	Orbiter Power Distribution Box (OPDB)	1.2.1.5.2	PCAS Cross Bay Member
1.1.1.1	28V Heater CCA	1.2.1.5.3	Cross Bay (Row 2)
1.1.1.2	Chassis	1.2.1.5.4	Cross Bay
1.1.2	ExPCA - "Coffin"	1.2.1.5.5	Cross Bay
		1.2.1.5.6	Cross Bay
		1.2.1.5.7	Cross Bay
		1.2.1.6	Diagonal Me
		1.2.1.7	Diagonal Me
		1.2.1.8	Diagonal Sid
		1.2.1.9	Trunnion Str
		1.2.1.9.1	Trunnion P
		1.2.1.9.2	Primary Er
		1.2.1.9.3	Secondary
		1.2.1.10	Scuff Plates
		1.2.1.11	Keel Interfa
		1.2.1.11.1	Keel Interfa
		1.2.1.11.2	Keel Trunn
		1.2.1.12	Splice Plate
		1.2.1.13	Shear Clam
		1.2.1.14	Brackets
		1.2.1.14.1	Bracket, C
		1.2.1.14.2	Bracket, C
		1.2.1.15	Closeout Pl
		1.2.1.16	Stanchion f
		1.2.1.17	Terminal bld
		1.2.1.18	Hardware
		1.2.2	GFE, Bracke
		1.2.2.1	PVGF (bot
		1.2.2.2	FRGF Bra
		1.2.2.3	ROEU/PD
		1.2.2.4	Plates/Pan
		1.2.2.5	Cargo Inte
		1.2.2.6	UMA Brea
		1.2.2.7	Orbiter Po
		1.2.2.8	Keel
		1.2.2.9	Trunnions
		1.2.2.10	Cargo Bay
		1.2.2.11	Sill Trunn
		1.2.2.12	Fittings
		1.2.2.13	Base
		1.2.2.14	Tubing
		1.2.2.15	Top
		1.2.2.16	Side
		1.2.2.17	Y Constraint
		1.2.2.18	Miscellaneous
		1.2.2.19	End Caps
		1.2.2.20	Passive Com
		1.2.2.21	Frame
		1.2.2.22	Aft Guide Pl
		1.2.2.23	Forward Gu
		1.2.2.24	Scuff Plate
		1.2.2.25	Clevis
		1.2.2.26	Cross Men
		1.2.2.27	Cross Men
		1.2.2.28	Cross Men
		1.2.2.29	Cross Men
		1.2.2.30	Cross Men
		1.2.2.31	Cross Men
		1.2.2.32	Cross Men
		1.2.2.33	Cross Men
		1.2.2.34	Cross Men
		1.2.2.35	Cross Men
		1.2.2.36	Cross Men
		1.2.2.37	Cross Men
		1.2.2.38	Cross Men
		1.2.2.39	Cross Men
		1.2.2.40	Cross Men
		1.2.2.41	Cross Men
		1.2.2.42	Cross Men
		1.2.2.43	Cross Men
		1.2.2.44	Cross Men
		1.2.2.45	Cross Men
		1.2.2.46	Cross Men
		1.2.2.47	Cross Men
		1.2.2.48	Cross Men
		1.2.2.49	Cross Men
		1.2.2.50	Cross Men
		1.2.2.51	Cross Men
		1.2.2.52	Cross Men
		1.2.2.53	Cross Men
		1.2.2.54	Cross Men
		1.2.2.55	Cross Men
		1.2.2.56	Cross Men
		1.2.2.57	Cross Men
		1.2.2.58	Cross Men
		1.2.2.59	Cross Men
		1.2.2.60	Cross Men
		1.2.2.61	Cross Men
		1.2.2.62	Cross Men
		1.2.2.63	Cross Men
		1.2.2.64	Cross Men
		1.2.2.65	Cross Men
		1.2.2.66	Cross Men
		1.2.2.67	Cross Men
		1.2.2.68	Cross Men
		1.2.2.69	Cross Men
		1.2.2.70	Cross Men
		1.2.2.71	Cross Men
		1.2.2.72	Cross Men
		1.2.2.73	Cross Men
		1.2.2.74	Cross Men
		1.2.2.75	Cross Men
		1.2.2.76	Cross Men
		1.2.2.77	Cross Men
		1.2.2.78	Cross Men
		1.2.2.79	Cross Men
		1.2.2.80	Cross Men
		1.2.2.81	Cross Men
		1.2.2.82	Cross Men
		1.2.2.83	Cross Men
		1.2.2.84	Cross Men
		1.2.2.85	Cross Men
		1.2.2.86	Cross Men
		1.2.2.87	Cross Men
		1.2.2.88	Cross Men
		1.2.2.89	Cross Men
		1.2.2.90	Cross Men
		1.2.2.91	Cross Men
		1.2.2.92	Cross Men
		1.2.2.93	Cross Men
		1.2.2.94	Cross Men
		1.2.2.95	Cross Men
		1.2.2.96	Cross Men
		1.2.2.97	Cross Men
		1.2.2.98	Cross Men
		1.2.2.99	Cross Men
		1.2.2.100	Cross Men

**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

## **Acknowledgements**

**Richard Fox – Program Planning and Control Manager**

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