

REPORT DOCUMENTATION PAGE

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6. AUTHOR(S) Michael O'Such				5d. PROJECT NUMBER	
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13. SUPPLEMENTARY NOTES For presentation at the AIAA Modeling and Simulation Conference, Portland, OR, 8-11 August 2011.					
14. ABSTRACT Modeling and simulation is a key enabler for the systems engineering process and can support the affordability goals for new programs by performing trade studies during the pre-acquisition phase of new programs. Modeling and simulation allows program managers and designers to assess the impact of system requirements and the introduction of new technologies early in the design phase and to assess alternative concepts, identifying the best approach to fulfill the requirements before significant funding has been expended. Advatech Pacific, Inc. (Advatech), is under the direction of the Air Force Research Laboratory (AFRL), and with their support is currently developing the Integrated System and Cost Modeling (ISCM) tool suite that addresses the impact of system requirements and technology insertion and explores trade spaces throughout the life cycle of a program.					
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Advatech Pacific

Changing The Way Engineering Is Conducted™



An Integrated Approach to Systems Engineering through Modeling and Simulation

Presenter:

Michael O'Such

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Distribution A: Approved for Public Release (PA# Pending)



Advatech Pacific, Inc. Background



An Aerospace Engineering Research & Development Company Founded in 1995 primarily focused on:

- Aerospace Vehicle Physics-based Modeling, Simulation and Analysis
- Electronic Communications System Interoperability
- Aerospace Engineering Design and Analysis Services



Past M&S Efforts



- IPAT (Effort Began: 2002)

- Expansion of Reusable Military Launch System (RMLS) developed at WPAFB
- Developed for rapid assessment of launch vehicle designs for AFRL/RZST
- Integration of industry standard tools (CEA, POST, MINIVER, DATCOM)
- Various propulsion types and vehicle types modeled

- ACES-ISET (Effort Began: 2003)

- Developed to fulfill the need for an overall space mission trade study tool for AFRL/RV
- Integrates the Space Mission and Analysis Design worksheet for spacecraft assessment and additional mass-estimating relationships for small satellites
- Models spacecraft radiation environment
- Unmanned Space Vehicle Cost Model, Small Satellite Cost Model, NASA Instrument Cost Model used to estimate spacecraft costs
- Integrates launch vehicles from a database of existing launch vehicle or can import a launch vehicle model from IPAT



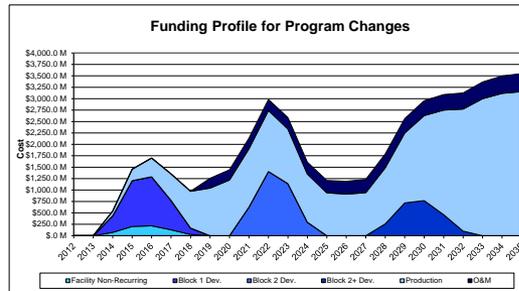
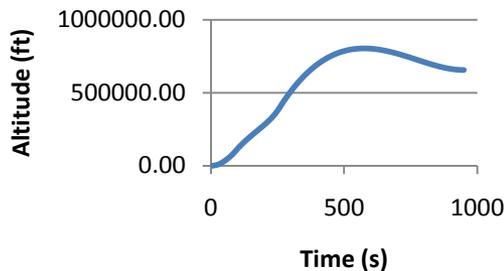
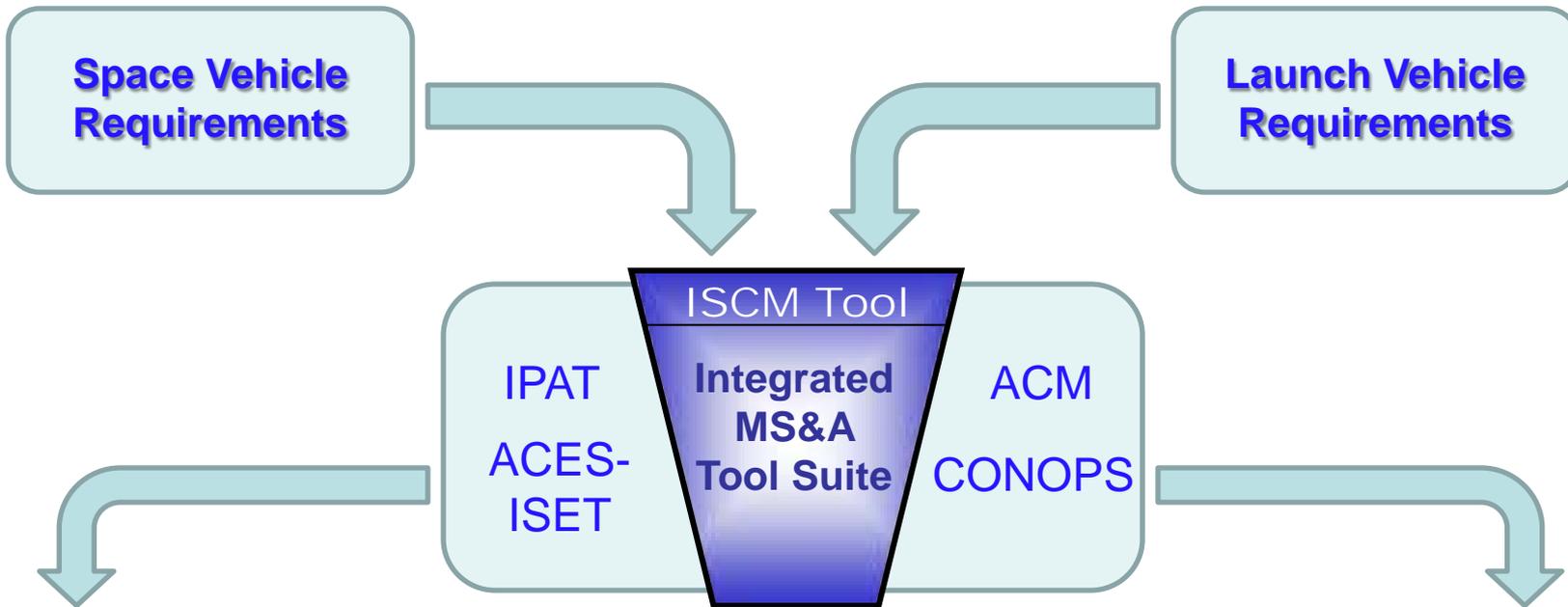
Past M&S Efforts



- ACM (Effort Began: 2006)
 - Uses CERs and acquisition strategies to estimate development, procurement and top-level launch costs for expendable and solid launch vehicles
 - CERs developed by Dr. Roy Smoker of MCR using historical program data, statistical analysis, and NASA and DoD TRLs
 - Incorporates risk assessment
 - Integrated with IPAT
- CONOPS (Effort Began: 2009)
 - Analysis of faculties and labor cost
 - Launch availability and reliability estimates
 - Generates baseline launch operations schedule
 - Integrated with IPAT and ACES-ISET



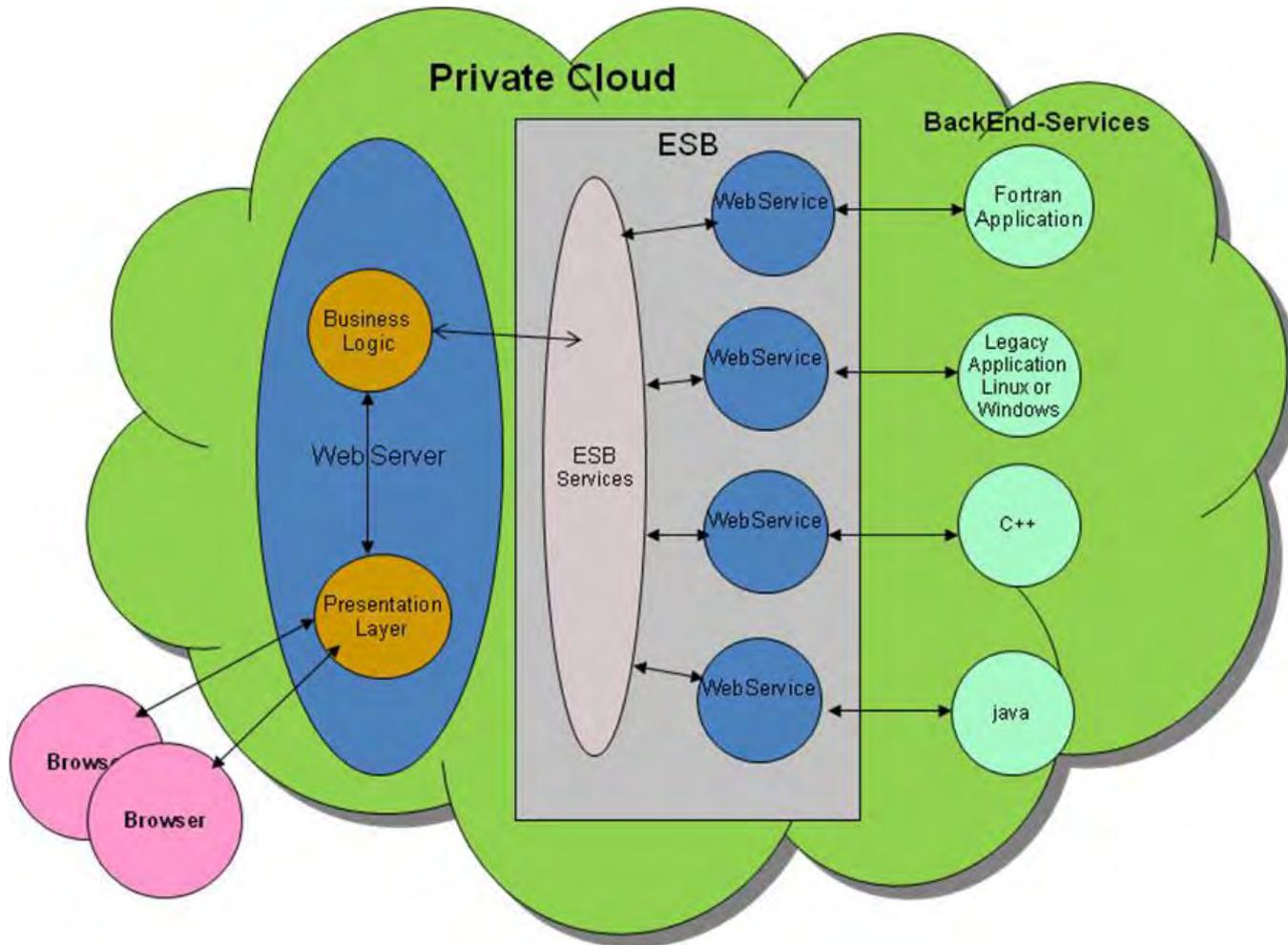
ISCM Integration Concept



Task ID	Phase	Work Description/Structure Elements	Duration
1	1	0 Stage Solid Horizontal Build	22.87 days
2	1.1	HB	5.27 days
3	1.1.1	HB	4.8 days
14	1.1.2	HB	4.67 days
38	1.2	Final LV-Int	8.6 days
92	1.3	F&P	7.6 days
104	1.4	Initial System	3.6 days
106	1.5	System Int	4.8 days
110	1.6	Final Int	6.6 days
118	1.7	Operational Ops	6.6 days
111	1.7.1	Ground Ops	Plan Mission
110	1.7.2	Ground Ops	Integrate Mission Vn
110	1.7.3	Ground Ops	Safe Pad
120	1.7.4	Ground Ops	Support Mission DM Pad
121	1.7.5	Ground Ops	Launch Mission Data
122	1.7.6	Ground Ops	Monitor Flight Ready
123	1.7.7	Ground Ops	Verify Launch Ready
124	1.7.8	Ground Ops	Perform DM Launch
125	1.7.9	Ground Ops	Shutdown and Erect Mast
126	1.7.10	Ground Ops	Verify Supporting Mast
127	1.7.11	Ground Ops	Shutdown System
128	1.7.12	Ground Ops	Mission Mission Ready
129	1.7.13	Ground Ops	Launch Mission
130	1.7.14	Ground Ops	Connect Mission Data
141	1.7.15	Ground Ops	Support Mission Data
142	1.7.16	Ground Ops	Support Mission Data
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ISCM Service-Oriented Architecture



Distribution A: Approved for Public
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Launch Vehicle Performance

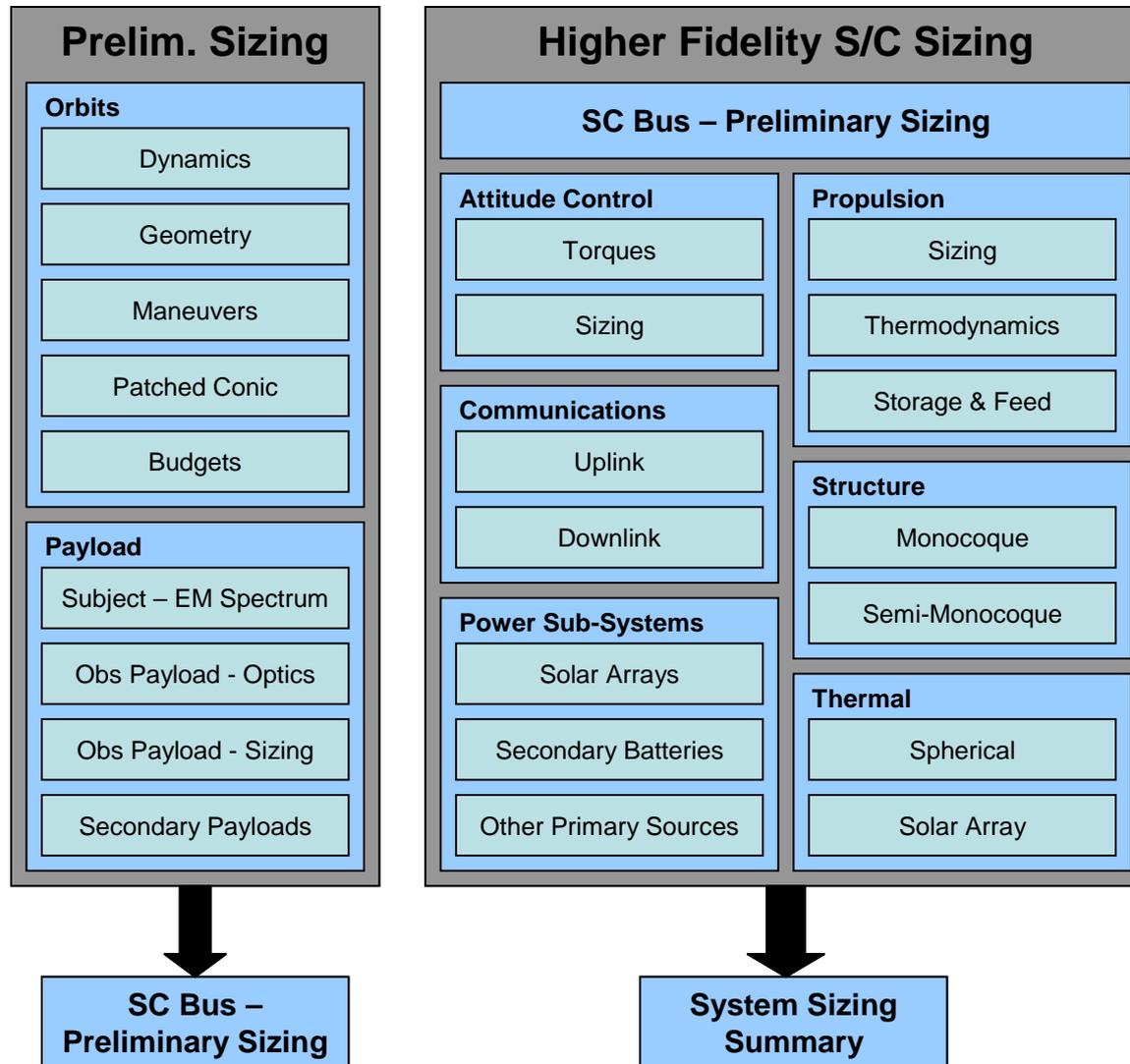


The screenshot displays a CAD software environment. On the left, the 'Model Tree' shows a hierarchical structure for a 'Launch Vehicle Designer' project, including components like 'Stage-1', 'Stage-2', 'interstage-1-2', 'Shroud', 'Payload-Adapter', 'payload', 'ELV Payload Payload', 'Flight-Conditions', 'Trajectory-Analysis', 'Orbital Mechanics System', 'STK', 'Avionics', 'Dimensions', and 'Model Change History'. The central 'Graphics Display' window shows a 3D model of a launch vehicle with a white nose cone, a yellow main body, orange boosters, and a green section near the base. The 'Mode' panel at the bottom left has options for 'Edit', 'Add', 'Shade', 'Inspect', 'Draw', 'Undraw', 'Expand', 'Wire Fr', and 'Delete', with 'All?' checked. The software title bar indicates 'Technosoft - Main Modeling Form - Model C:\IPAT\Mo'.

Distribution A: Approved for Public release (PA#)



Space Vehicles



Distribution A: Approved for Public release (PA#)



Launch Vehicle Cost Analysis



- Parametric Estimation: $AUC_i = \alpha_i W_i^{\beta_i}$
- Historical data derives cost-estimating relationships (α and β values)
- CERs tied to TRLs and project milestones (PDR, CDR, etc)
- Complete life-cycle costs with risk analysis (FRISK) incorporated



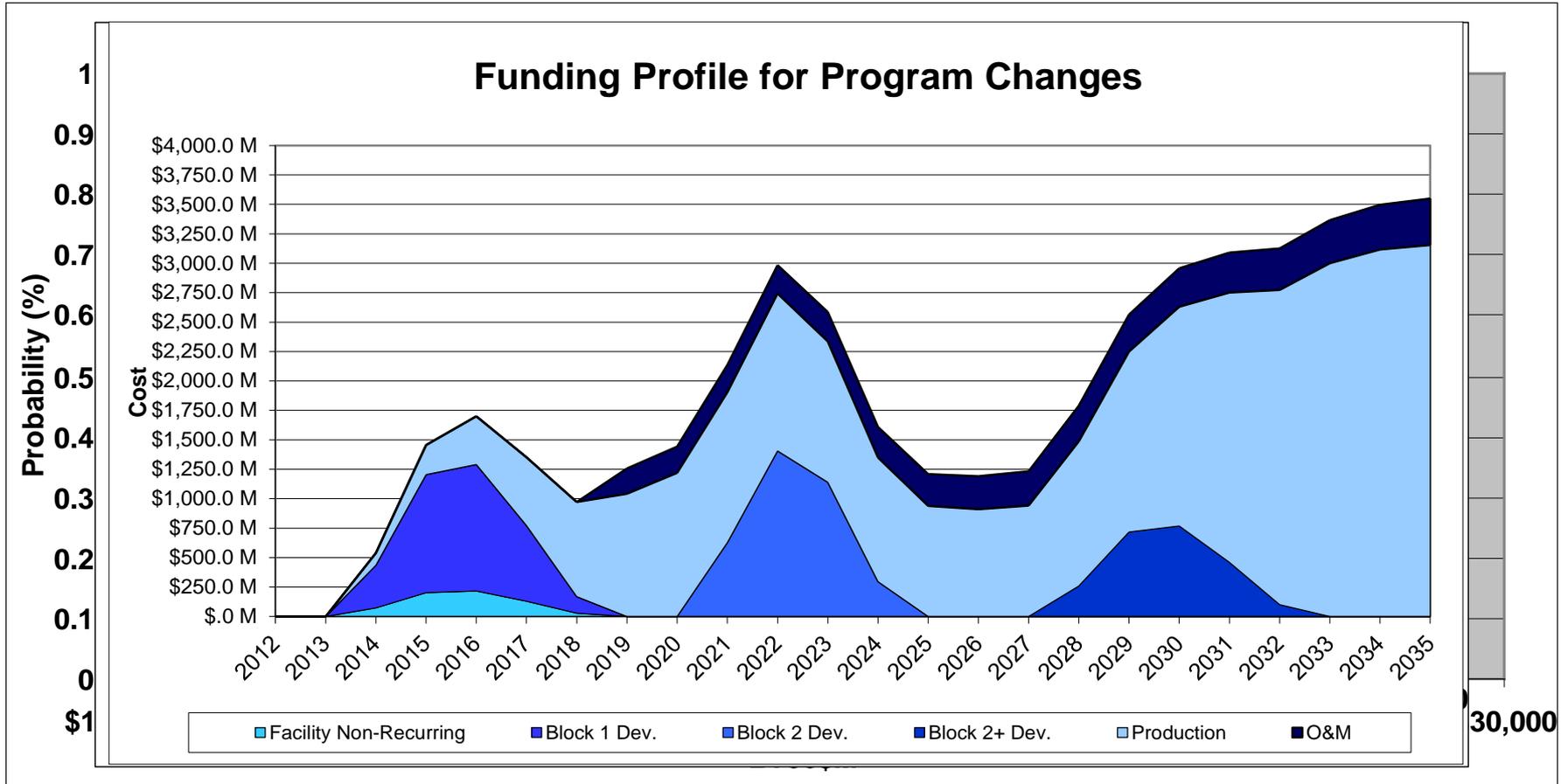
Launch Vehicle Cost Analysis



TRL	NASA	Defense Acquisition Management Framework
1	Basic principles observed and reported	Paper studies of alternative concepts for meeting a mission
2	Technology concept and/or application formulated	Analysis of alternatives; Validated and approved needs Statement (MNS); Exit criteria: Having specific concept to be pursued and technology exists
3	Analytical and experimental critical function and/or characteristic proof of concept	Concept in hand, but system architecture to be developed; Exit criteria: Development Contract Awarded
4	Component and/or breadboard validation in laboratory environment	Architecture complete, but components need to be integrated into complete system; Exit criteria: Preliminary Design Review (PDR)
5	Component and/or breadboard validation in relevant environment	System prototypes demonstrated in relevant environment; Exit criteria: Critical Design Review (CDR)
6	System/subsystem model or prototype demonstration in a relevant environment	System demonstrated in its intended environment; Exit criteria: System Verification Review (SVR)
7	System prototype demonstration in a space (if applicable) environment	Technically Mature; Low Rate Initial Production; Exit Criteria: Initial Operational Capability (IOC)
8	Actual system demonstration and "flight qualified"	Initial Operational Capability; System operationally effective; Exit Criteria: Manufacturing ready for full-rate production
9	Actual system "flight-proven" through successful mission operation	Full-rate production; Deploy System; Exit Criteria: Full Operational Capability



Launch Vehicle Cost Analysis



Distribution A: Approved for Public release (PA#)



Space Vehicle Cost Analysis



- Excel-based model includes several validated cost models
 - Unmanned Space Vehicle Cost Model (USCM)
 - Small Satellite Cost Model (SSCM)
 - NASA Instrument Cost Model (NICM)
 - Constructive Cost Model II (COCOMO II)
- Air Force Cost Analysis Agency (AFCAA) Schedule Estimating Relationships
- FRISK used to apply risk to life-cycle costs



Space Vehicle Cost Analysis



- Cost model outputs:
 - RDT&E
 - First unit cost
 - Additional unit cost
 - Total cost
- Heritage factors applied to RDT&E
- Bus and payload information used to generate total RDT&E
- Generated cost used to determine IA&T, PL and GSE cost
- Outputs broken down by WBS



Operations and Maintenance



The screenshot displays the CONOPS software interface. The main window is titled 'CONOPS -' and has a menu bar with 'File', 'Edit', 'View', 'Defaults', and 'Help'. Below the menu bar is a toolbar with icons for file operations. The main area is divided into several sections:

- COST MODEL(S)**: A tree view on the left showing 'Vehicle0' expanded, with sub-items like 'Mission-Setup', 'Satellite', 'Fleet-Readiness', 'Availability', 'Facilities', 'Reliability-Survey', 'Surge Analysis', 'Labor', 'Training', and 'Cost Summary'.
- Model Name**: 'Vehicle0'.
- Mission Characterization**: Includes radio buttons for 'Planned Launch Rate' (selected), 'Prompt Global Strike', and 'On Alert'. There are also radio buttons for 'Operationally Responsive Space'. Fields for 'Operational Support (Yrs)' (0) and 'Start Year' (0) are present. A 'Schedule' section has radio buttons for 'Then Year' (selected) and 'Base Year'. Below are radio buttons for 'Days/Week' (5, 6, 7), 'Shifts/Day' (1, 2, 3), and 'Hours/Shift' (8, 10, 12). A 'Sync Schedule to MissionOps' button is at the bottom.
- Vehicle Configuration**: Includes 'Vehicle Type' (Expendable), '# Stages' (dropdown), 'Stage 1 Type' (Liquid), 'Strap On' section with 'Type' (Solid/Liquid), 'Number of Stages' (0), and 'Parallel Burn' checkbox. 'Launch Location' is set to 'Cape'.
- Values History** and **Values History Comments**: Empty panels on the right.
- Page Comments**: 'Old Comments' and 'Add Page Comments' buttons at the bottom left.

A 'Change IPAT Vehicle' dialog box is open in the foreground, containing the following fields:

- Advanced Cost Model**: 'Acquisition Strategy' (Normal Development and Production).
- Costs**: 'AUC-Procurement (\$Millions)' (0), 'AUC-Production (\$Millions)' (0), 'AUC-Development (\$Millions)' (0), and 'Total Launch Costs (\$Millions)' (0).
- IPAT**: 'Vehicle Type' (Expendable), 'Number of Boosters' (0), 'Number of Stages' (0), 'Boosters Reusable' (No).
- Stages**: Four rows for Stage 1-4, each with 'Type' (Liquid), 'Weight (lbm)' (0), 'Length (ft)' (0), and 'Diameter (ft)' (0).
- Strapon**: 'Strapon Type' (Solid), 'Strapon Weight (lbm)' (0), 'Strapon Diameter (ft)' (0), and 'Parallel Burn' (No).
- Payload**: 'Payload Weight (lbm)' (0), 'Payload Length (ft)' (0), 'Shroud Weight (lbm)' (0), and 'Shroud Diameter (ft)' (0).
- Max Wind Speed (kts)**: (0).

Buttons for 'OK' and 'Cancel' are at the bottom right of the dialog box.

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Operations and Maintenance



COST MODEL(S)

- Vehicle0
 - Mission-Setup
 - Satellite
 - Fleet-Readiness
 - Availability
- Facilities
 - Site
- Cost
 - Reliability
 - Surge
 - Labor
 - Training
 - Cost S

Cost Detail

Total Summary in Millions of Dollars

Total Facility Cost: 904.093

COST MODEL(S)

Total Number of Flights:

Number of Prior Flights:

Run Failure Rate Analysis

	Flights	Failure Rate	Exp. Failures
Test Flights	5	0.53	2.64
Start up	10	0.36	3.55
Growth	25	0.19	4.72
Mid Life	60	0.08	4.95
Maturity	0	0.04	0.00

Total Exp. Failures:

Roads and Grounds	\$ 0	\$ 9,4329	\$ 9,4329
Specialized Equipment	\$ 2,3284	\$ 0	\$ 2,3284

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Previous Studies (cont'd)

Stage	Nominal Dry Weight (lbm)	Achieved Dry Weight (lbm)	Weight Difference (lbm)	Nominal Loaded Weight (lbm)	Percent Difference (% total stage weight)
Minotaur I Second Stage	1524	1753	229	15,506	1.5
Minotaur I First Stage	4,955	5,055	100	50,885	0.2

Four Launch Vehicles Modeled In ISCM
Delta II, Atlas V, Minotaur I, Falcon 1
Modeled weights within 2% of published values

TacSat -5 Concept Evaluations

- Thirteen Concepts for TacSat - 5 Evaluated Using Tool Suite
- Identified requirements not met and inaccurate understated estimates

Integrated Project Team

ISCM Tool

- Cost
- Risk
- CONOPS
- Schedule
- Operability
- Performance

Knowledge Database Buildup



Results

ORS Seven Sisters Mission Cost

Procurement and total mission cost estimate for ORS missions and launch scenarios -

Completed in less than 7 days

Within 5% of other independent estimates

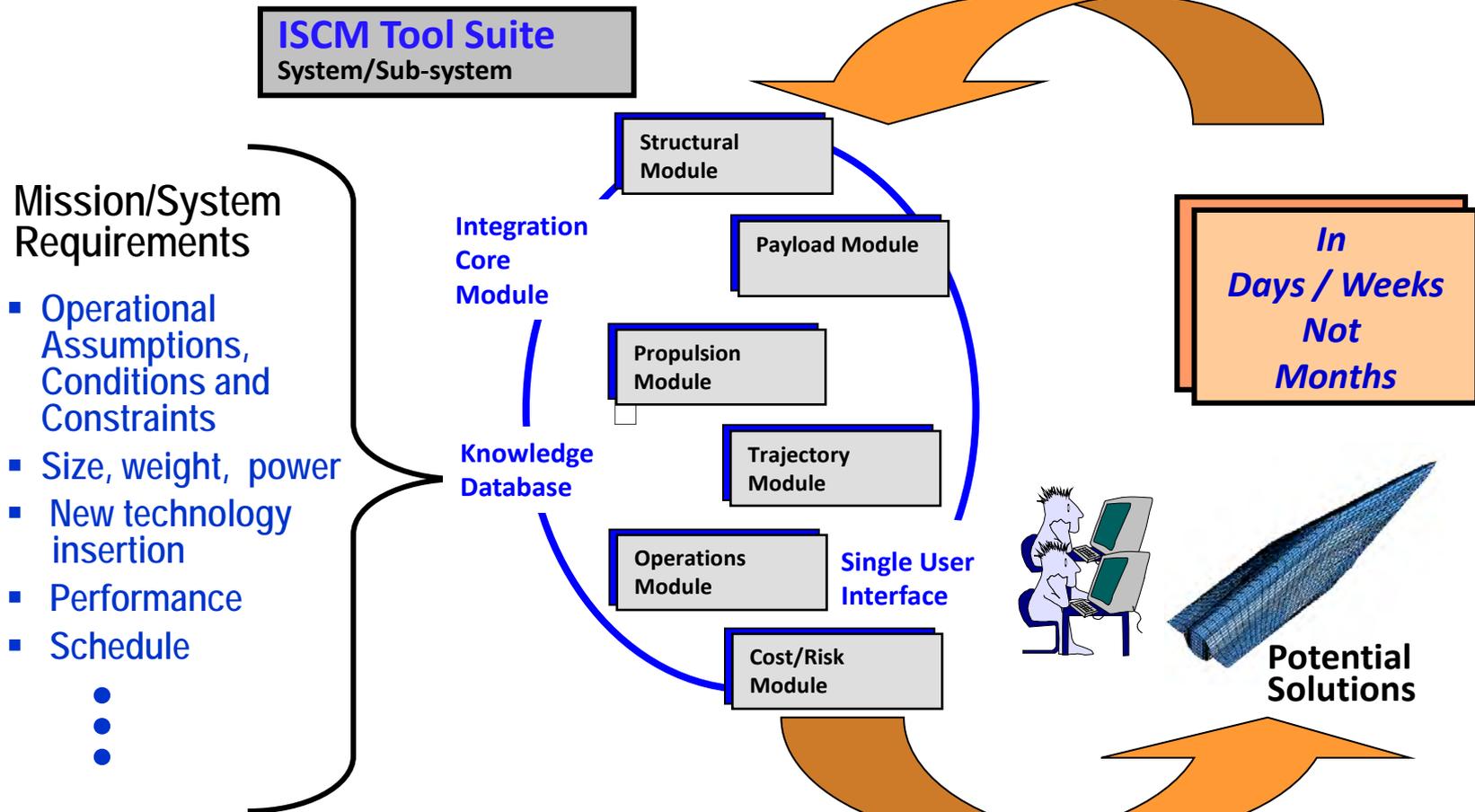


Summary

Solution to Early Design Challenges of High-Performance Complex Systems

Integrated optimizing tools provide:

Feedback



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Future Work



- Improved trajectory optimization for heavily constrained problems
- Enhanced mass estimating relationship
- Increase fidelity of risk assessment
- Improve historical data
- Model additional vehicle classes:
 - Aircraft
 - Rotorcraft
 - Armored vehicles
 - Transport vehicles
 - Communication networks



Questions?



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