

Advanced Technology Lifecycle Analysis System (ATLAS) Technology Tool Box (TTB)

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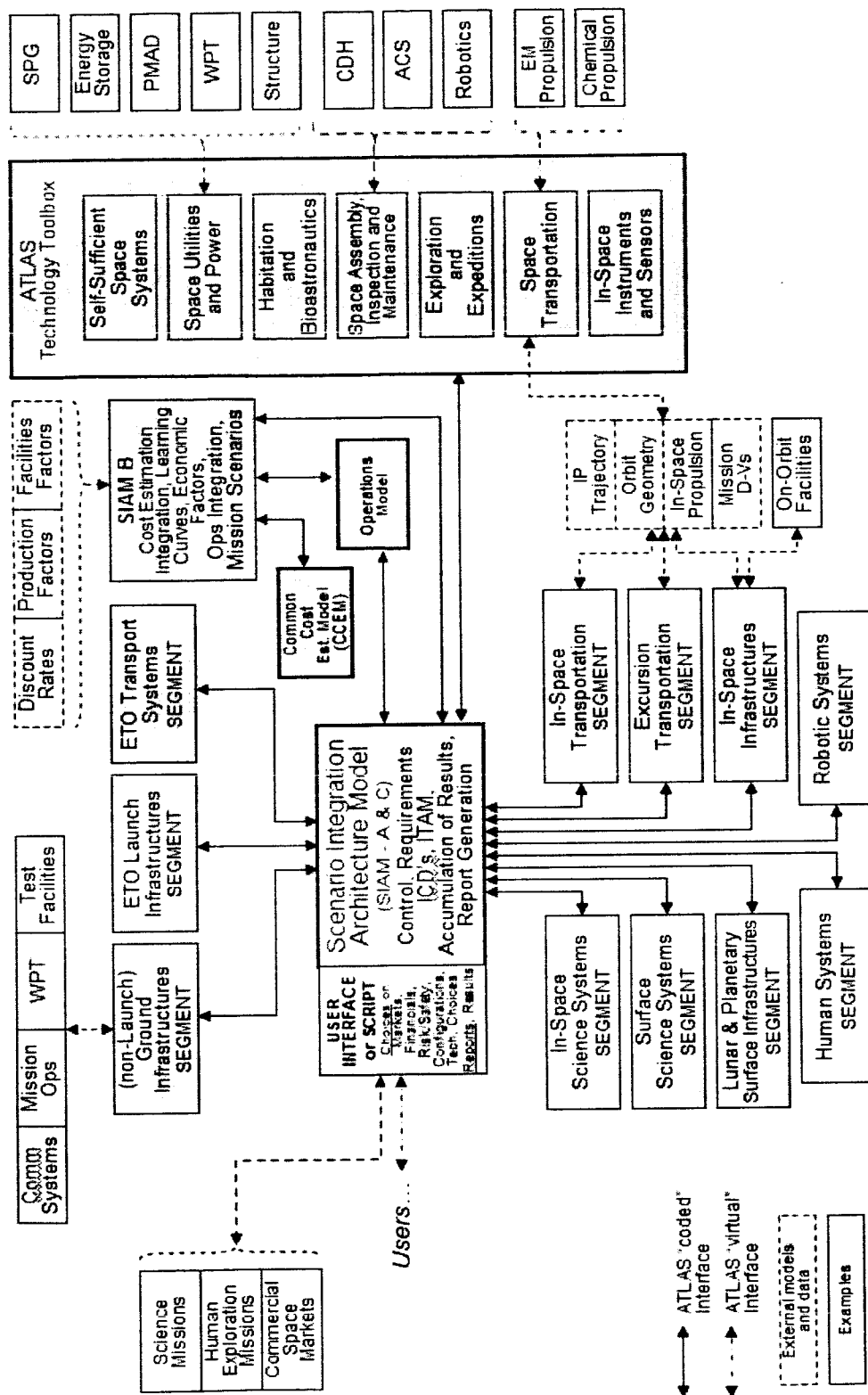


Advanced Technology Lifecycle Analysis System

- Decision support tool designed to aid program managers and strategic planners in determining how to invest technology R&D dollars.
- Excel-based modeling package that allows a user to build complex space architectures and evaluate the impact of various technology choices.
- ATLAS contains system models, cost & operations models, campaign timeline and a centralized technology database.
 - Each element in the architecture is modeled by a separate Excel workbook.
 - VBA macros control the flow of data.
 - Output from one model (*mass of lunar lander*) may be required input to another model (*launch vehicle*).
 - Model info needs to be passed to Cost and Operations models.
 - Technology data drawn from centralized technology database.

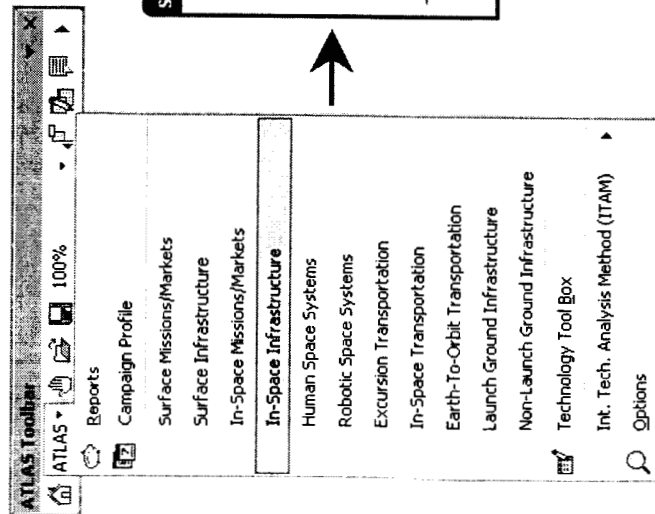


ATLAS Architecture Overview

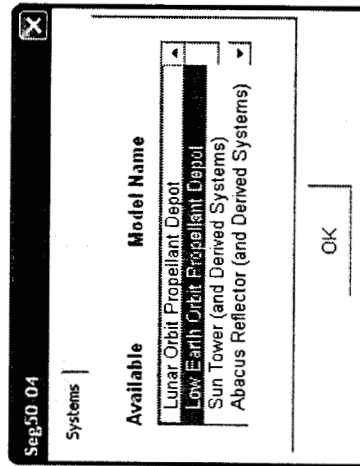


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Example ATLAS Set-up



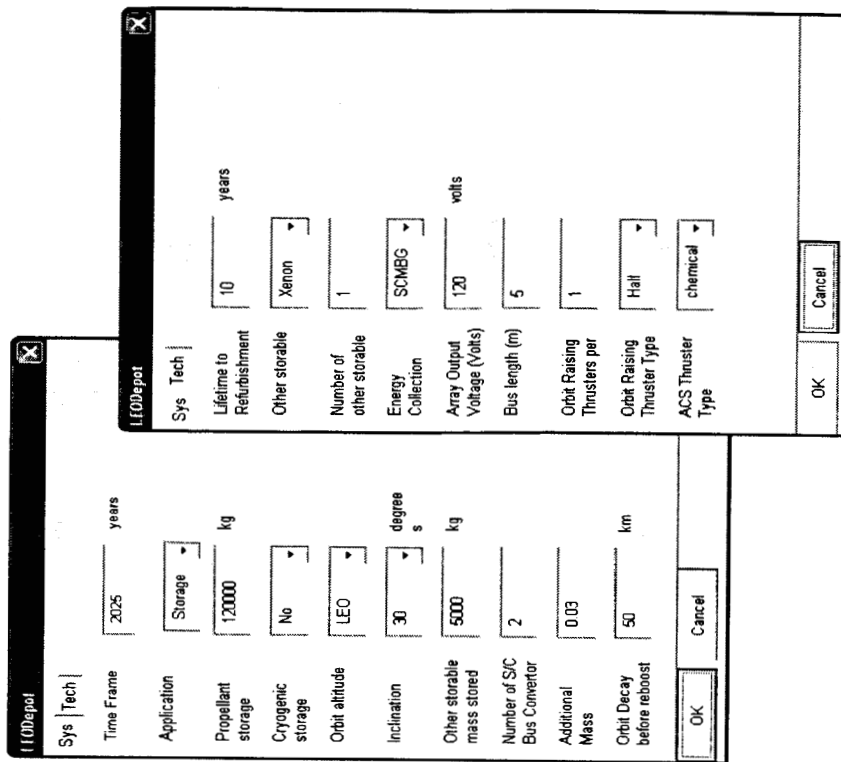
In-Space
Infrastructure
segment is
selected.



System choices are:

LO Depot
LEO Depot
Sun Tower
Abacus
ISC

Space Solar Power
configurations



System and Technology
options for LEO Depot.



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The TechTables page (contained in each system model) is the interface between the model and the TTB.

TechTables page is tailored to the technology needs of each model.

Macros load TTB data into this page during run-time.

TechTables page
provides a “one-stop-shop” for technology data within the model.



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ATLAS / TTB Interface

[illegible]

ATLAS Technology Tool Box

- Technology data for all system models is drawn from a common database, the ATLAS Technology Tool Box (TTB).
- The TTB provides a comprehensive, architecture-independent technology database that is keyed to current and future timeframes.
- **Key advantages of separate/central TTB:**
 - central location for updates, additions, etc.
 - technologies are not re-defined by separate modelers
 - technology metrics are applied consistently across all modeled system elements
 - high visibility for the technology assumptions and metrics that drive the ATLAS results.



Structure of the ATLAS TTB

- Framework for the TTB is provided by the Advanced Systems, Technologies, Research and Analysis (ASTRA) program.
- ASTRA is a comprehensive collection of road maps, priorities, gap analysis results and metrics for the development of future space flight capabilities for human and robotic exploration.
- ASTRA (and ATLAS) WBS is formulated around the requirements for Exploration Systems.
- The Level 1, or Top Tier, WBS elements are:
 1. Supporting Technology Research
 2. Advanced Technology Development
 3. Systems-Level Technology Demonstrations
 4. Advanced Systems Development
 5. Systems Integration, Analysis, Concepts and Modeling.



ATLAS Work Breakdown Structure

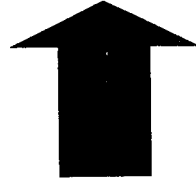
Level 1 (a.): Top Tier: distinguishes between systems integration, analysis, concepts and modeling; advanced capability-focused technology development and demonstrations; and basic research and technology.

Level 2 (a.b): Strategic Themes: these represent major architectural elements and technologies that must be developed or advanced in order to achieve the goals set forth by the Exploration Systems.

Level 3 (a.b.c): Technology Element: particular notional capabilities or options for a given Strategic Theme.

Level 4 (a.b.c.d): Technology Sub-Element: functional technologies and concepts necessary to realize Technology Element capabilities or options.

Level 5 (a.b.c.d.e): Technology Option: specific technologies to be developed, matured and demonstrated throughout the Spiral Development.



Exploration Systems Spiral Development

Spiral development is an evolutionary acquisition strategy in which a system is developed in which the end-state requirements are not known at program initiation. Those requirements are refined through system development and demonstration, risk management and continuous user feedback

Spiral 1 Focus on development of a Crew Exploration Vehicle: high-level milestones are the flight of a prototype in 2008; an un-crewed CEV in 2011; and a first crewed CEV flight in 2014.

Spiral 2 Focus in human lunar return: capabilities for extended human and robotic exploration on the Moon will be developed by 2020.

Spiral 3 Begin using the Moon as a test bed for Mars by 2023.

Spiral 4 Focus on (1) deployment of a launch vehicle for use in Mars exploration and (2) expanded lunar activities including in-situ resource utilization by 2026.

Spiral 5 Introduce interplanetary transportation vehicle and support infrastructure to take humans to Mars and beyond by 2029.

Spiral 6 Introduce systems to Mars surface by 2032 to enable future human excursions on the Martian surface.

Spiral 7 First human mission to Mars by 2035.



TTB Data Format

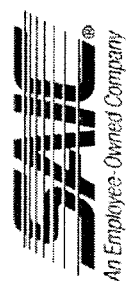
2.2.1_Solar Power Generation				STATUS	Template, Metrics & Prelim data	TIME FRAME 0			TIME FRAME 1		
WBS	THEME	TECHNOLOGY	TECHNOLOGY	NAME	METRIC	METRIC	METRIC	METRIC	METRIC	METRIC	METRIC
				TECH	NAME	UNITS	TYPE	VALUE	VALUE	VALUE	PROBABILITY
				OPTION				(Thresh- hold)	(Coal)	(Thresh- hold)	Distribution
2.2.1.1	Space Utilities and Power	Solar Power Generation	PV Solar Arrays	Single Crystal MBG	Energy Conversion Type	By Name	Tech- Primary	PV Conversion	PV Conversion	PV Conversion	Predicted Type - TBD
2.2.1.1.1	Space Utilities and Power	Solar Power Generation	PV Solar Arrays	Single Crystal MBG	Efficiency @ "Cell-Level" (at 1 AU)	%	Tech- Primary	PV Conversion	PV Conversion	PV Conversion	Predicted Type - TBD
2.2.1.1.1	Space Utilities and Power	Solar Power Generation	PV Solar Arrays	Single Crystal MBG	Power per Unit Mass @ "Blanket-Level" (at 1 AU)	W/kg	Tech- Primary	PV Conversion	PV Conversion	PV Conversion	Predicted Type - TBD
2.2.1.1.1	Space Utilities and Power	Solar Power Generation	PV Solar Arrays	Single Crystal MBG	Efficiency @ "Array-Level" (at 1 AU)	%	Tech- Primary	PV Conversion	PV Conversion	PV Conversion	Predicted Type - TBD
2.2.1.1.1	Space Utilities and Power	Solar Power Generation	PV Solar Arrays	Single Crystal MBG	Array Degradation per Year	%	Tech- Primary	PV Conversion	PV Conversion	PV Conversion	Predicted Type - TBD
2.2.1.1.1	Space Utilities and Power	Solar Power Generation	PV Solar Arrays	Single Crystal MBG	Operating Temperature	Degree C	Tech- Primary	PV Conversion	PV Conversion	PV Conversion	Predicted Type - TBD
2.2.1.1.1	Space Utilities and Power	Solar Power Generation	PV Solar Arrays	Single Crystal MBG	Expected Operational Lifetime	Hours	Operations- P	Predicted Type - TBD	Predicted Type - TBD	Predicted Type - TBD	Predicted Type - TBD
2.2.1.1.1	Space Utilities and Power	Solar Power Generation	PV Solar Arrays	Single Crystal MBG	Mean Time Between Failure (MTBF)	Hours	Operations- P	Predicted Type - TBD	Predicted Type - TBD	Predicted Type - TBD	Predicted Type - TBD
2.2.1.1.1	Space Utilities and Power	Solar Power Generation	PV Solar Arrays	Single Crystal MBG	Current Technology Readiness Level (Average)	TRL (1-9)	Tech R&D- P	Predicted Type - TBD	Predicted Type - TBD	Predicted Type - TBD	Predicted Type - TBD
2.2.1.1.1	Space Utilities and Power	Solar Power Generation	PV Solar Arrays	Single Crystal MBG	Anticipated R&D Degree of Difficulty (Average)	R&D3 (1-5)	Tech R&D- P	Predicted Type - TBD	Predicted Type - TBD	Predicted Type - TBD	Predicted Type - TBD

Performance metrics differ among technologies. Technologists identify performance for use by system engineers in parametric sizing equations. Metrics should include mass, area, power, energy density, etc.

Operations data includes metrics for sizing workforce, facilities and processing timelines.

Programmatic metrics are standardized across all technologies. These metrics include TRL, R&D³ and TNV.

Columns represent 12 timeframes starting in 2005 and extending 33 years in 3 year increments. Technologists estimate the improvement in performance and operations and the funding required to mature the technology.



Performance Metrics

- Performance Metrics consist of technical data used by model developers and system engineers to size a subsystem or component within a spreadsheet model.
- The performance metrics specified for a given technology may be unique to that technology.
 - Solar Power Generation performance metrics:
 - power per unit mass at array-level (kW/kg)
 - concentration ratio (numeric)
 - Energy Storage performance metrics:
 - battery depth of discharge (%)
 - cell voltage (V)
 - ETO Propulsion (engines) performance metrics:
 - maximum rated thrust (N)
 - specific impulse (sec)



Operations Metrics

- *Operations metrics* describe the effect a given technology choice has on the time and labor force required to maintain, process or operate that subsystem as well as the overall architecture.
- **Examples:**
 - Expected Operational Lifetime
 - estimated number of operational hours that a given technology will function before it can no longer perform as required.
 - For example, in the absence of catastrophic failures, technologies such as solar cells will gradually degrade until they are unable to generate the power required by the system.
 - Operational Difficulty Factor (ODF)
 - indicates the level of difficulty introduced by the choice of a given technology relative to some reference, state-of-the-practice, technology with an ODF of 1.0.
 - range: 0.1 – 10
 - $ODF < 1 \rightarrow$ selected technology should simplify Ops and, therefore, the reduce Ops cost relative to the reference technology.
 - $ODF > 1 \rightarrow$ selected technology should increase the level of effort required for operations.



Programmatic Metrics

- *Programmatic metrics* describe the maturity of the technology as well as the difficulty and level of financial investment inherent in improving the performance metrics or advancing the maturity level.
- Programmatic metrics include the Technology Readiness Level (TRL), anticipated Research and Development Degree of Difficulty (R&D³), Technology Need Value (TNV) and the projected investment in technology R&D and maturation.



ATLAS TTB Time Frames

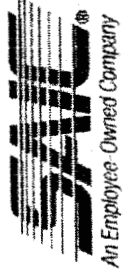
- Data for each metric of each technology is collected for the current state-of-the-art as well as projected values for future timeframes.
- These projected values will be used to evaluate the performance of architectures to be developed in the future.
- The ATLAS TTB timeframes correspond to the Exploration Systems exploration milestones.

Timeframe	Year range
0	2005 (state-of-the-art)
1	2005-2008
2	2008-2011
3	2011-2014
4	2014-2017
5	2017-2020
6	2020-2023
7	2023-2026
8	2026-2029
9	2029-2032
10	2032-2035
11	2035-2038



Timeframe Data

- Each timeframe contains to following values:
 - Metric Value (Threshold)
 - Metric Value (Goal)
 - Metric Probability Distribution
 - Selected from drop-down list of Probability Distribution Functions (PDFs)
- Current working definitions of Goal and Threshold values:
 - Goal → Expected Value of the PDF
 - Threshold → 3σ value associated with PDF
- Future versions of the TTB may carry a single metric value at each timeframe and eliminate the probability distribution.



Data Collection and Validation

- **Accuracy of ATLAS results relies on the accuracy of the data in the TTB.**
- **Data Collection**
 - Primary source of data is the community of experts active in R&D in a particular area. Data is collected during ATLAS Technology Interchange Meetings (TIMs) which bring together technologists, modelers and end-users.
 - Additional data is collected from reports documenting previous study results, e.g. Revolutionary Aerospace Systems Concepts (RASC) and the Capability, Requirements, Analyses and Integration (CRAI) team reports.
 - Timeframe 0 (state-of-the-art) can also be found in published specifications.
- **Data Validation**
 - Interactive TIMs provide a forum for discussion and validation.
 - Comparing ATLAS output with results from previous studies or actual missions provides insight into data validity.

