Space Propulsion Synergy Team
Industry • Government • Entrepreneurs • Academia

A NASA Spaceliner 100 Propulsion Oriented Technology Assessment

July 19, 2000

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About the Subject

- SPACELINER 100 (SL 100)
- Is not a program for development of a specific advanced space transportation system concept
- Is a technology plan/roadmap for enabling a RLV/Gen3 space transportation system
- The Space Propulsion Synergy Team (SPST) Is an independent diversified team from industry, government and academia.
- The Technology Assessment Process utilized a "marriage" of the standard SPST process and the Analytical Hierarchy Process (AHP).

Major Objectives of the Briefing

1. Provide an understanding of the products of the technology assessment and prioritization workshop.

2. Increase knowledge of the assessment process utilized and why.

3. Stimulating interest in applying this process to many other space endeavors.

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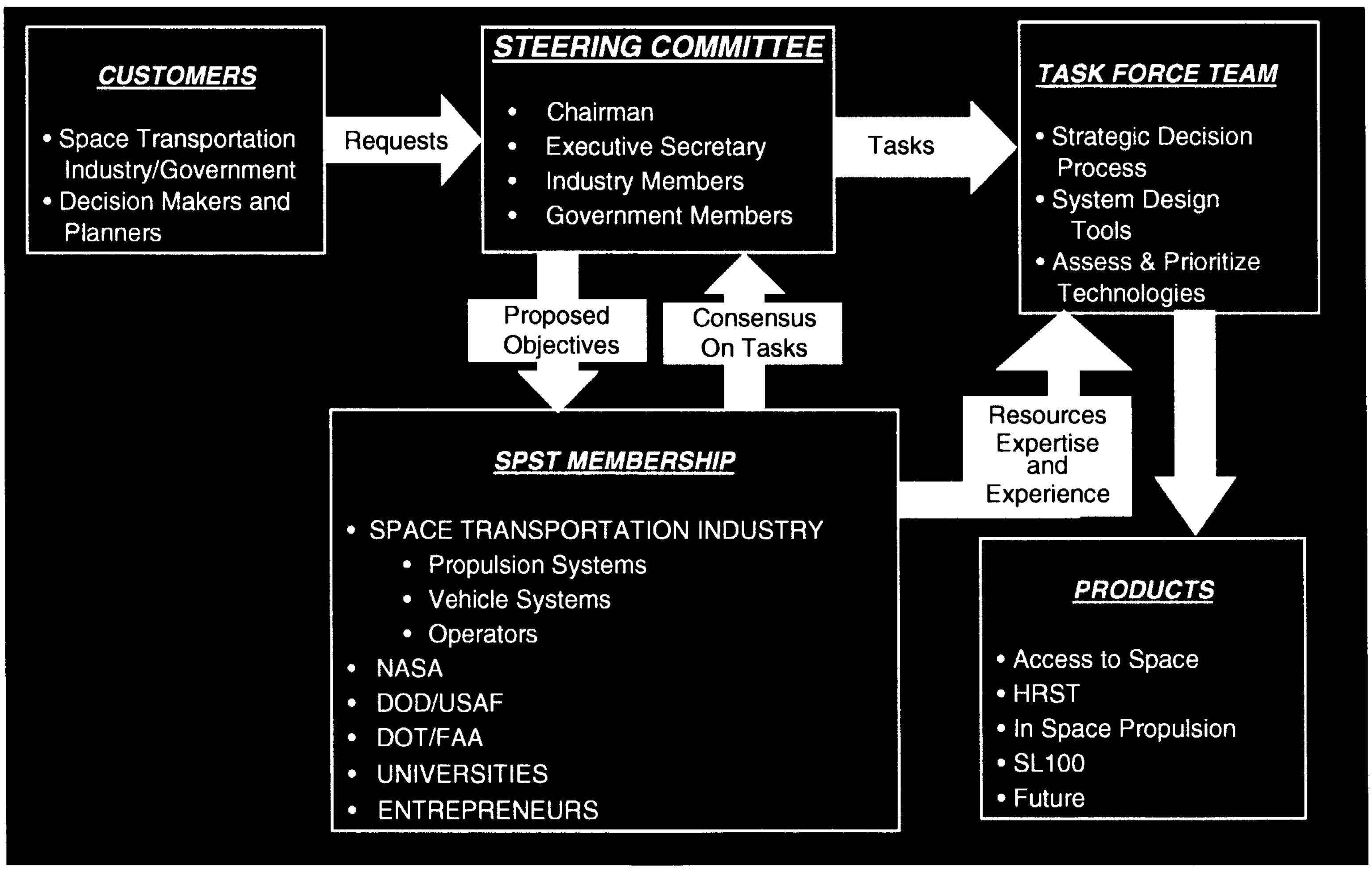
Mode of Operation



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SPACELINER 100 TECHNOLOGIES STUDY
SPST SUPPORT TASK FORCE

Leader – Walt Dankhoff, SPST Executive Secretary
Customer Representative – Uwe Hueter, MSFC

Team #1
Transportation Service Functional Requirements
Leader - Russ Rhodes, KSC
Jim Bray, Lockheed Martin
Robert Bruce, SSC
Ray Byrd, Boeing/KSC
Dave Christensen, Lockheed Martin
Mark Coleman, CPIA
Walt Dankhoff, SAIC
Bryan DeHoff, FIU
Bill Escher, SAIC
Uwe Hueter, MSFC
Glenn Law, Aerospace
Dan Levack, Rocketdyne
Keith Dayton, Boeing

Team #2
Transportation Service Architectures
Leader – John Robinson, Boeing
Ray Chase, ANSER
Dave Christensen, Lockheed Martin
Bill Escher, SAIC
Larry Hunt, LRC
Roger Lepsch, LRC
Carey McCleskey, KSC
Dr. John Olds, Georgia Tech.
Jay Penn, Aerospace Corp.
Keith Dayton, Boeing
Bill Hufferd, CPIA

Team #3
Candidate Technologies
Leader – Dan Levack, Rocketdyne
Frank Bealmanno, TRW
Mike Blair, Thiokol
Joe Cassidy, Primex
Dave Gallet, Aerojet
Uwe Hueter, MSFC
Glenn Law, Aerospace Corp.
Chuck Marshall, Lockheed Martin
Bill Taylor, GRC
Edgar Zapata, KSC
Charles Simonds, ARC
Jerry Sanders, JSC
Eric Hurlbert, JSC
Mike Gaunce, ARC
Bill Kahle, ARC rep @ MSFC

Team #4
Technologies Prioritization
Leader – Pat Odom, SAIC
Daric Escher, SAIC
Wayne Goode, SAIC
Dan Levack, Rocketdyne

Technical Design Criteria Evaluators (See Section VII)

Factors Evaluators (See Section VII)

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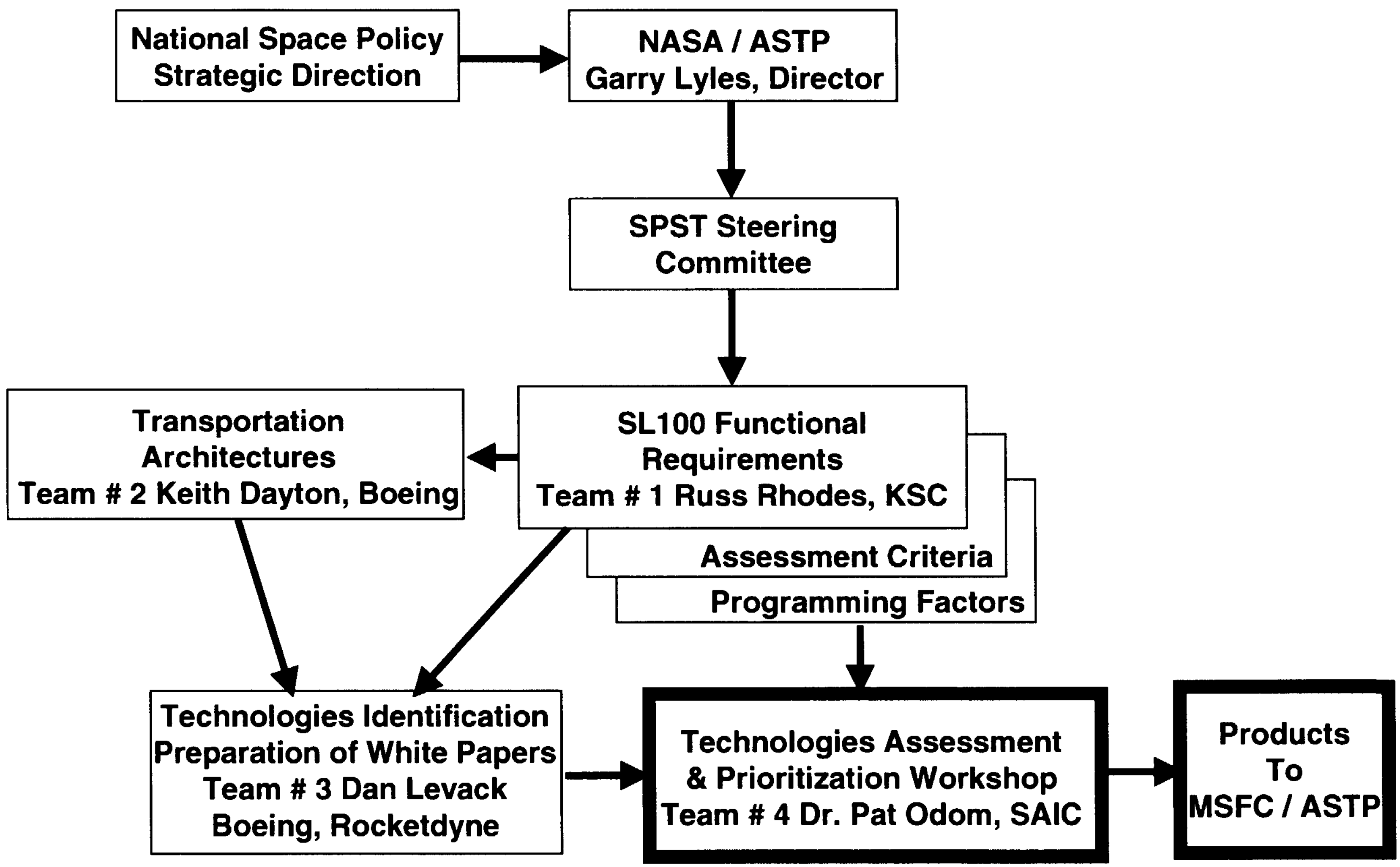
Work Flow Plan



Strategic Direction for RLV Gen3

- Assuring reliable and affordable access to space through U.S. transportation capabilities is fundamental to achieving national space goals.
- Must improve reliability, operability and responsiveness to be in concert with achieving the Safety and Cost goals for 3drd Generation Space Transportation.
- Safety: Aircraft-Levels of Flight Safety Paramount
- Cost: $100 per pound to Orbit equivalent
- Service: Capable of <u>supporting all Earth Orbit</u> transportation requirements, including all orbits from LEO to GEO
- Customers: Must support Space Transportation needs of Commercial, Civil, DOD, and National Security.

Summary of Functional Requirements for RLV/Gen (Spaceliner 100)

The Attributes of a Space Transportation System

Affordable / Low Life Cycle Cost Min. Cost Impact of Payloads on Launch Sys. Low Recurring Cost Low Cost Sensitivity to Flight Growth Operation and Support Initial Acquisition Vehicle/System Replacement **Dependable** Highly Reliable Intact Vehicle Recovery Mission Success Operate on Command Robustness Design Certainty **Environmental Compatibility** Minimum Impact on Space Environ. Minimum Effect on Atmosphere Minimum Impact all Sites **Public Support** Benefit GNP Social Perception	**Responsive** Flexible Capacity Operable Process Verification Auto. Sys. Health Verification Auto. Sys. Corrective Action Ease of Vehicle/System Integration Maintainable Simple Launch on Demand Easily Supportable Resiliency **Safety** Vehicle Safety Personnel Safety Public Safety Equipment and Facility Safety
During the Technology R&D Phase:	During the Program Acquisition Phase:
Affordable / Low Life Cycle Cost Cost to Develop **Benefit Focused** **Schedule** **Risk** **Dual Use Potential**	**Affordable / Low Life Cycle Cost** Cost to Acquire **Schedule** **Risk** **Technology Options** **Investor Incentive**

Operating

How do we improve in all these phases?

Programmatics

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Example of Correlation (Weighting) of Design Criteria with the Attributes "Affordable and Dependable"

Affordable/Low Life Cycle Cost
Min. Cost Impact on Launch Sys.
Low Recurring Cost
Low Cost Sens. To Flt. Growth
Operation and Support
Initial Acquisition
Vehicle/System Replacement

	Raw Score	% Weight
of unique stages (flight and ground) (-)	483	5.3%
of active on-board space sys. req'd for propulsion (-)	454	4.9%
On-board Propellant Storage & Management Difficulty in Space (-)	453	4.9%
Technology readiness levels (+)	425	4.6%
Mass Fraction required (-)	387	4.2%
Ave. ISP on refer. Trajectory (+)	310	3.4%
of umbs. Req'd to Launch Vehicle (-)	276	3.0%
of engines (-)	274	3.0%
Resistance to Space Environment (+)	268	2.9%
Integral structure with propulsion sys. (+)	239	2.6%
Transportation trip time (-)	211	2.3%

Dependable
Highly Reliable
Intact Vehicle Recovery
Mission Success
Operate on Command
Robustness
Design Certainty

	Raw Score	% Weight
No. 10 # of active components required to function including flight Operations (-)	527	5.7%
Design Variability (-)	464	5.0%
of different fluids in system (-)	404	4.4%
of active engine systems required to function (-)	247	2.7%
of modes of cycles (-)	227	2.5%
Margin, mass fraction (+)	215	2.3%
Margin, thrust level/engine chamber press (+)	211	2.3%
of engine restarts required (-)	**201**	**2.2%**

PREPARATION & BRIEFING OF TECHNOLOGY "WHITE PAPERS"

Enabling/Generic Technologies:
- Aerodynamic performance and control through drag modulation **(Ray Chase/ANSER)**
- High performance hydrocarbon fuels **(Joe Ciminski)** – by phone
- Thrust augmentation **(Mike Blair/Thiokol)**
- Propulsion IVHM **(June Zakrajsek/GRC)** – by phone
- Numerical propulsion system simulations (NPSS) for space transportation propulsion **(Karl Owen/GRC)** – by phone
- High (better than densified density hydrogen) **(Bryan Palaszewski /GRC)** – by phone
- Advanced cryotank structures **(Earl Pansano/Lockheed Martin)**
- Long life, light weight propulsion materials and structures **(Dan Levack/Boeing-Rocketdyne)**
- Bridge to space (tether second stage) **(Tom Mottinger/Lockheed Martin)** – by phone
- Green, operable RCS **(Eric Hurlbert/JSC** and **Stacy Christofferson/Primex)** by phone Two different concepts

Flight Systems:
- Baseline/Pivot Technology for Main Propulsion and OMS/RCS **(Dan Levack/Boeing-Rocketdyne** and **Stacy Christofferson/Primex)**
- Long life, high T/W hydrogen rocket **(Dan Levack/Boeing-Rocketdyne)**
- Long life, high T/W hydrocarbon rocket **(Uwe Hueter/MSFC)**
- Hydrocarbon TSTO RBCC **(Dick Johnson/Aerojet)** – by phone
- SSTO hydrogen RBCC **(Dick Johnson/Aerojet)** – by phone
- TSTO hydrogen airbreather **(Bill Escher/SAIC)**
- SSTO TBCC airbreather **(Bill Escher/SAIC)**
- Pulsed detonation engine rocket **(Dan Levack/Boeing-Rocketdyne)**
- Airbreathing pulsed detonation engine combined cycle **(Dan Levack/Boeing-Rocketdyne)**

Ground Systems:
- Baseline/Pivot technology for ground systems **(Edgar Zapata/KSC)**
- Advanced checkout and control systems **(Edgar Zapata/KSC)**
- Intelligent instrumentation and inspection systems **(Edgar Zapata/KSC)**
- Advanced umbilicals **(Edgar Zapata/KSC)**
- On-site, on-demand production and transfer of cryogenics **(Edgar Zapata/KSC)**

List of Technical Programmatic Evaluators

1. Kevin Bowcutt, The Boeing Company
2. Roger Campbell, Boeing Rocketdyne
3. Drew DeGeorge, Air Force Research Laboratory
4. Bruce Farner, Air Force Research Laboratory
5. Mike Groves, Lockheed Martin
6. Dr. Clark Hawk, University of Alabama in Huntsville
7. Merl Lausten, Aerojet
8. Tom Meredith, NASA Stennis Space Center
9. Dave McGrath, Thiokol
10. Dennis Petley, NASA Langley Research Center
11. Jay Penn, Aerospace Corporation
12. W. T. Powers, NASA Marshall Space Flight Center
13. Costante Salvador, Pratt & Whitney

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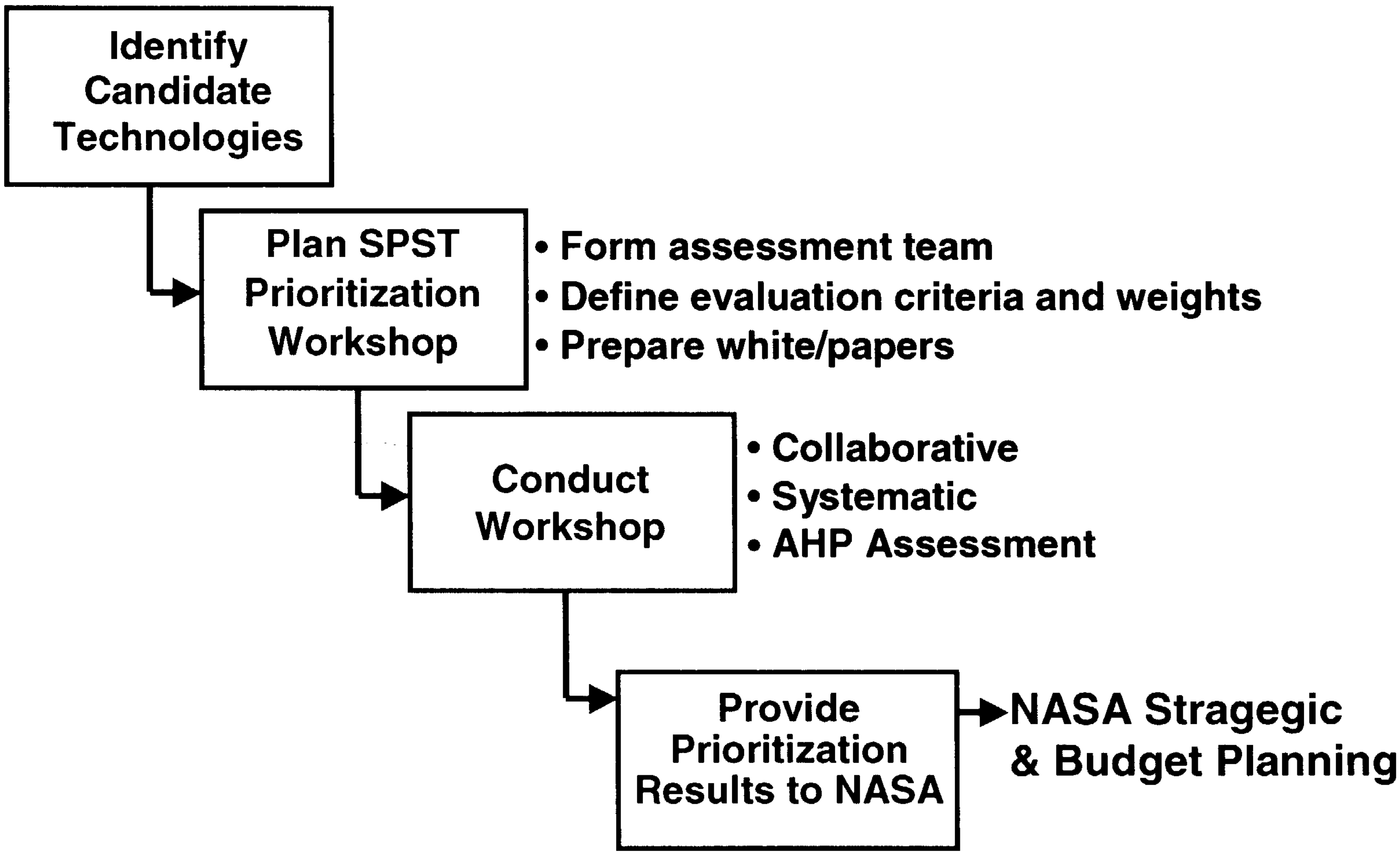
Overall Technologies Prioritization Process



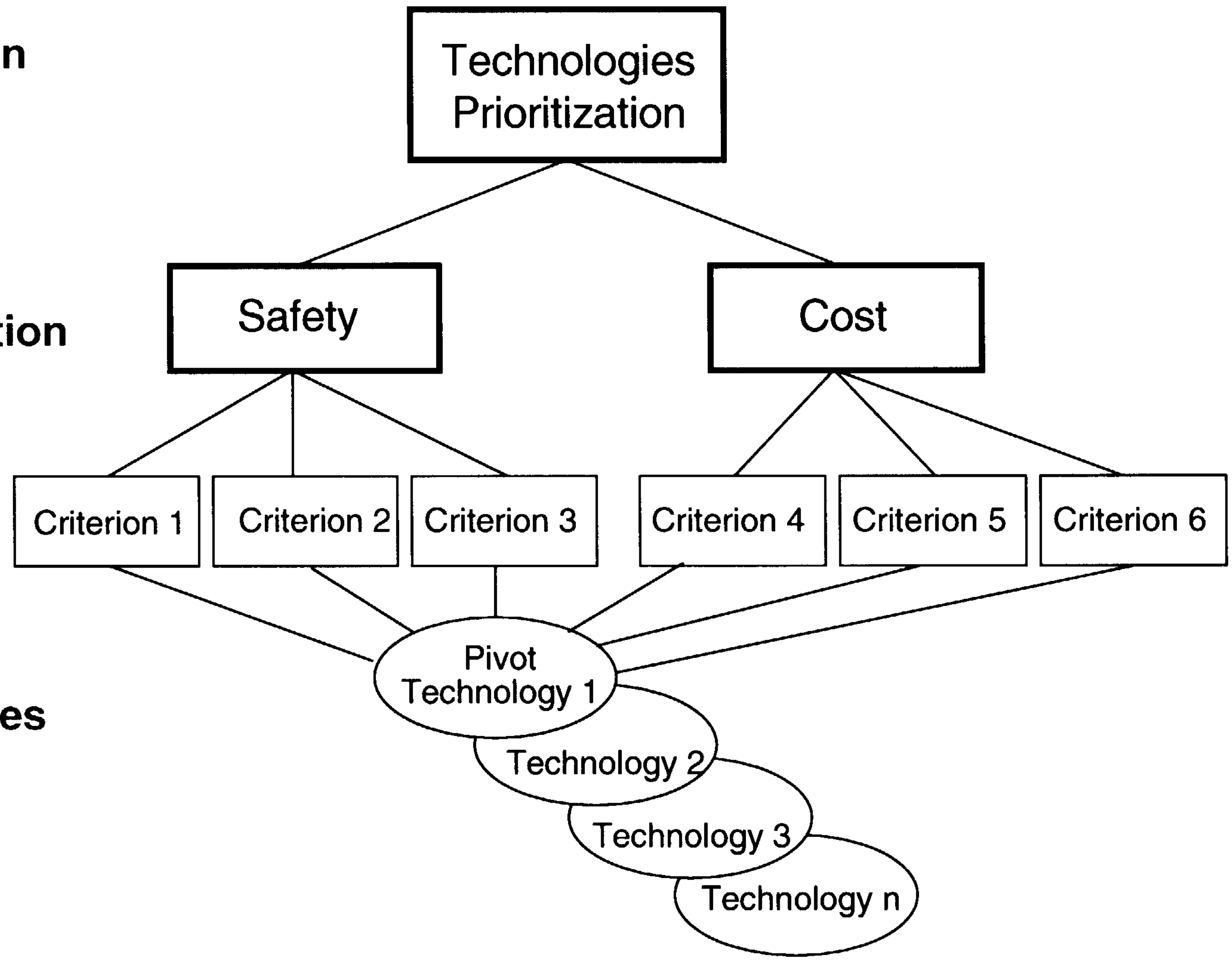
Overall Technologies Prioritization Process (Cont'd)

Prioritization Focus

Space Transportation Goals

Evaluation Criteria

Candidate Technologies



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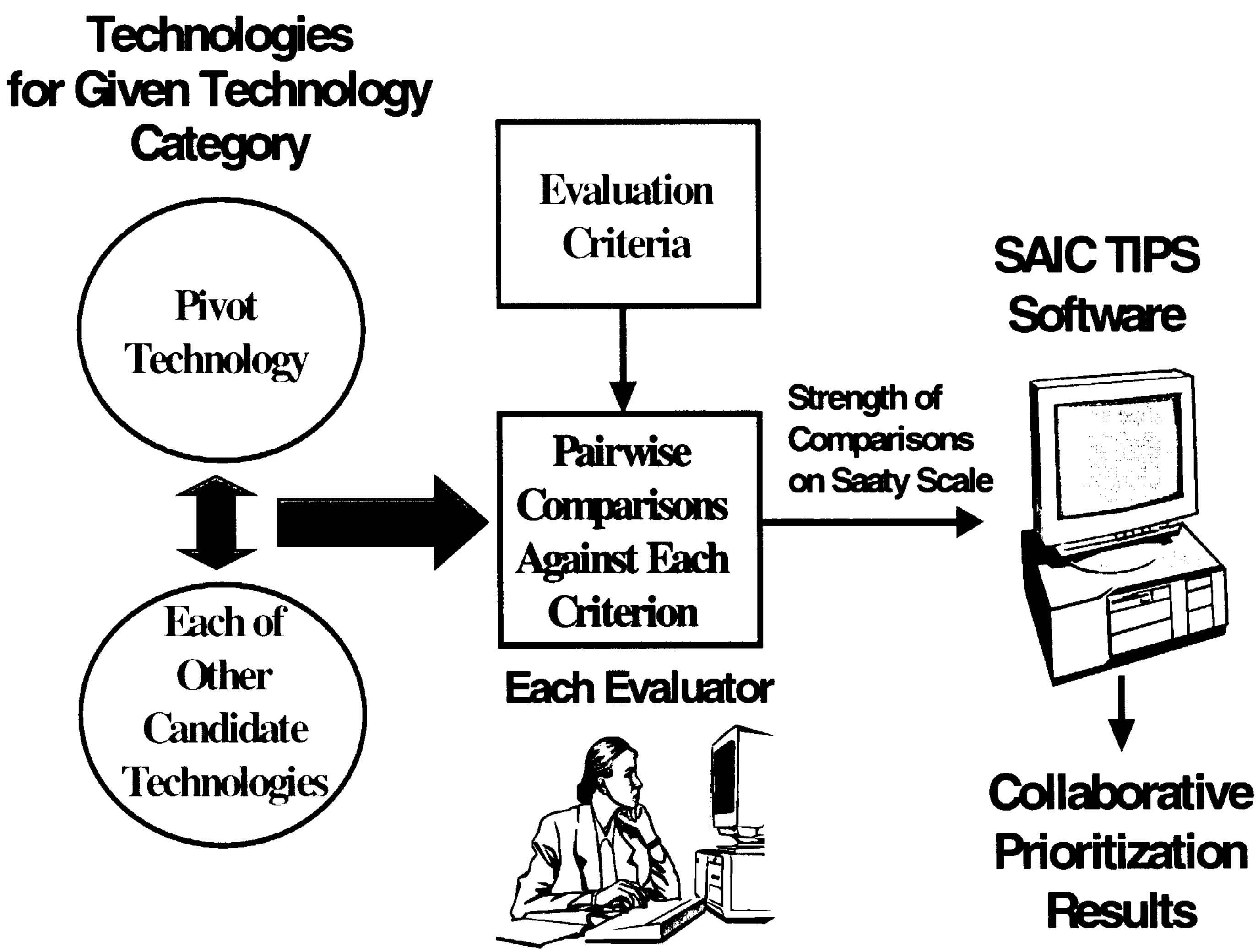
Overall Technologies Prioritization Process (Cont'd)



SPST Spaceliner 100
Propulsion Technologies

Priorities by Technology Category and Top Level Criterion
Enabling/Generic Technologies
Technical

Technology	Priority
Combined OMS/RCS	0.133
Propulsion IVHM	0.114
Green propellant	0.111
Long life, light weight propulsion materials and structures	0.100
NPSS for space transportation	0.097
Advanced cryotank structures	0.096
Aerodynamic performance/control through drag modulation	0.088
High performance hydrocarbon fuels	0.084
Bridge to Space	0.061
Thrust augmentation	0.061
High density hydrogen	0.055

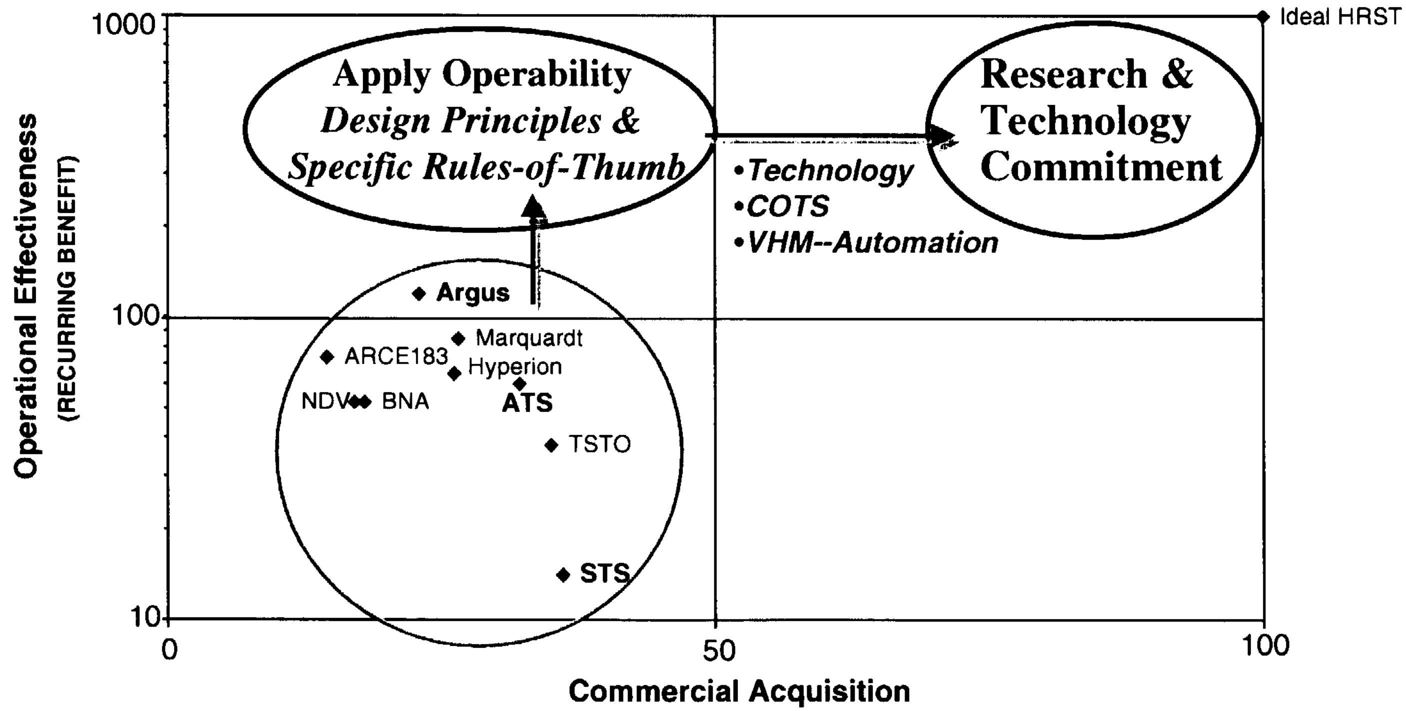
SPST Spaceliner 100
Propulsion Technologies (Cont'd)

Priorities by Technology Category and Top Level Criterion
Enabling/Generic Technologies
Programmatic

Technology	Priority
Advanced cryotank structures	0.137
Long life, light weight propulsion materials and structures	0.137
Propulsion IVHM	0.120
NPSS for space transportation	0.110
Combined OMS/RCS	0.097
Thrust augmentation	0.090
Aerodynamic performance/control through drag modulation	0.083
Green propellant	0.075
High performance hydrocarbon fuels	0.072
High density hydrogen	0.064
Bridge to Space	0.024

HRST Architectural Assessment

Preliminary Results



Operational Effectiveness vs. Non-Recurring Investment Commitment

Concluding Remarks

- SPST Task Force Provided Timely Support for the SL100 Technology Planning
- Conduct and Facilitation of Assessment and Prioritization workshop successfully
- Lessons Learned will be incorporated in Future SPST Support endeavors
- Several Prospective Future SPST activities in support of advanced space transporation both RLV/Gen 2 and RLV/Gen 3
- The continuing support by all the member organizations and individuals is very much appreciated