N92-11090

NUCLEAR THERMAL PROPULSION WORKSHOP OVERVIEW

John S. Clark
Workshop Chairman
NASA Lewis Research Center
Cleveland, OH

In the October/November issue of Air and Space Magazine (the quarterly magazine of the Smithsonian Air and Space Museum) the cover story was "Destination Mars, What Kind Of Rockets Will Get Us There." I think this article talks about why we are here today (Figure 1). We are here to try to figure out how to use nuclear propulsion to accomplish that mission, and we appreciate the help that we will be receiving from all of you.

I have a very detailed purpose statement in the handout (Figure 2). I am not going to read the words for you, but the bottom line is included in the last paragraph, to assess the state-of-the-art, to try to identify which of those concepts that have been proposed have the most benefit for the manned mission to Mars, to identify the technologies that need to be developed, to lay out some first-order plans for those technologies, and to try to get a first-order cost estimate, and from there to put together our project plan.

There is also included in the handout a listing of the members of the steering committee (Figure 3). You have met Gary Bennett, Earl Wahlquist, and Tom Miller, and Roger Lenard will be joining us. There are also a number of ex-officio members of the steering committee, including Franklin Chang-Diaz, who is an active astronaut at Johnson at this time; he has been included to bring in the astronaut safety aspects.

Figure 4 tries to show what we are trying to accomplish, and how we are going to do it. Back about the first of May, we got together in Washington and agreed upon an approach that looks very similar to the final approach that we are using for these workshops. We identified a large number of concepts that are candidates for this kind of a mission to Mars, and we tried to identify an appropriate person who could be a spokesperson (or Concept Focal Point - CFP) for that concept at these workshops. At the same time, we tried to define some requirements for the mission; Stan Borowski will talk about that baseline reference mission to Mars in his presentation, which will follow this one.

Based on those common requirements then, each of the concept focal points were to address their concept and how to do the mission, the kinds of technologies that would be required to perform that kind of a mission in terms of lifetime, endurance, reliability, safety and all of those things.

We put together Technology Review Panels (Figure 8-12) that are a national community of experts, if you will; they are here and will be sitting in on the parallel sessions, evaluating each of the concepts based on the four criteria: cost, safety, benefit to the mission, and technical risk.

Each of the concept focal points will present a brief summary of their concept, something on how that concept would perform on the mission, what the critical tests are, schedule, milestones, costs, and facilities.

The technology review panels then are going to use that information, prepare recommendations, and make a final presentation to the steering committee in September.

This is a quick summary of how we are going to get through the next three days (Figure 5). All day today and through 9:15 a.m. tomorrow, we will be meeting in this plenary session, where each of the concept focal points will give a brief summary of their concepts. We will then break into parallel working sessions starting at 9:30 a.m. tomorrow and running through about 10:30 a.m. on Thursday. From 10:30 through lunch the panels will caucus and put together their remarks for a plenary feedback session in the afternoon on Thursday; we should break about 3:30 p.m. on Thursday.

We also have a number of special information presentations (Figure 6) that I included in the agenda and I want to just mention some of them. The first one I have already talked about; Stan Borowski is going to talk about the reference mission from which we will "Delta" each of the other concepts. All of the evaluations will be performed compared to that baseline "reference" mission design.

Stan Gunn from Rocketdyne is going to talk a little bit about some of the things that we can do to NERVA that will upgrade that system for changes in the past 20 years.

Press Layton is going to talk about some dual mode concepts. Tonight at the banquet, Peter Worden will have some remarks. Peter is on the National Space Council. Then Brian Pritchard from NASA Langley will be here. He is involved with some of the Space Station Freedom studies and so he is going to talk about the work that is planned to get us from the space station, in its initial configuration, to the Space Exploration Initiative.

There are a number of other special presentations that I am not going to describe, but they will be of special interest to the panels, but that we felt might not be covered in as much detail by the concept focal points.

Figure 7 is a list of the concept focal points as you have in your agenda . I want to point out on the agenda that Dick Dahlberg from GA called me yesterday and he will not be able to attend.

Dilip Darooka from GE has worked on hybrid propulsion systems and he asked for about ten minutes in our plenary session this morning to present some of that material, so we will do that in place of the "pulsed nuclear" presentation. We also have, in addition to the solid core concepts, some liquid core, gaseous core and one paper by Bruce Reid on the NTP/NEP hybrid systems.

I would like to highlight some the members on the technology review panels. In the mission analysis area (Figure 8), Tim Wickenheiser from NASA Lewis is the panel chairman and Mike Stancati from SAIC is the executive secretary.

Ned Hannum is the chairman of propulsion panel (Figure 9) and the executive secretary for this panel will be Stan Borowski, both from NASA Lewis.

The reactor panel (Figure 10) is chaired by John Dearian from INEL and the executive secretary is Harvey Bloomfield from NASA Lewis.

The advanced development plans panel (Figure 11) is chaired by Steve Howe from Los Alamos and Darrell Baldwin is the executive secretary.

The safety panel (Figure 12) is integrated with the other four panels, with members from the safety panel distributed among the other four. They will be addressing the safety issues in each of those panels and then will caucus at the end of the workshop and will put together their separate report. Buzz Sawyer from NASA Headquarters is the chairman of that panel and Marland Stanley from INEL is the executive secretary.

I would like to emphasize the expected output from the workshop (Figure 13). For each of the concepts, we are looking for the critical test requirements, what needs to be done to develop that concept to a technology readiness level six. As indicated, we are working to technology readiness level six (TRL-6)-full system ground testing complete. We want to identify any safety issues with each of those concepts and we would certainly want to identify the facility requirements. And then once we have looked at all of the different concepts, we will be making a first order comparison based on their performance, the mission benefits, technical risk and a first cut at the development cost to TRL-6. Again, it's not a selection process, we are not trying to "down-select" and we are not trying to eliminate any concepts. We are simply trying to identify technology needs so that we can then put together our project plans.

In the assessment procedure (Figure 14) that's to be used, each of the five panels will be addressing the criterion that are identified. The output from the panels will be a written narrative from everyone in the workshop as well as the technology review panel members. That narrative should include discussions of strengths and weaknesses. And then the technology review panel will be doing a relative ranking and a comparison of each concept to the reference system.

Each of you have in your folder an evaluation worksheet (Figure 15) that we would like you to fill out. I encourage you to start filling those out during the summary sessions today and then to transfer them into your three-ring binder to keep the evaluation sheets together with the proper presentation; otherwise if you wait until the end of the session, at the end of all of the presentations you will not remember your comments. So I encourage you to write your comments as we are going along. Then after each concept has been presented in the parallel session, turn those sheets into the Executive Secretaries. He will collect them and we then will have that information available to us.

I want to talk very briefly about some of the factors that each panel will be looking for. In the mission analysis panel (Figure 16), they are looking for the benefit to the mission, how does it accomplish the mission better than the baseline system. Some of the factors are indicated here, initial mass in lower earth orbit or trip time, and they trade-off against each other. Specific impulse is an important measure of performance, and they will be looking at all of the mission safety and operations aspects. They will also address commonality, if that's appropriate, and we'll need to be thinking about whether or not the concept can be ready for TRL-6 in the 2006 time period. And of course they will be looking for inherent design reliability and/or complexity.

Indicated on the right side of the chart is the very simple scoring system that we will use. We have developed a consistent scoring system where the score of (3) represents the same (in this case) mission benefit or performance as the baseline system. There are two levels of performance less than the baseline, and two levels of performance better than the baseline, so the panel will be making an initial first cut at those kinds of discriminators.

The same approach is to be used in the propulsion technology panel (Figure 17). They will be looking at technical risk for developing the concept, and will ask the concept focal points to try to rate the concept on the technology readiness level scale; I will talk about what that means on my next chart. And then each evaluator will have a chance to decide whether he agrees with that rating or not. The factors that they will be considering are: where the concept really is - how mature is the technology. It's probably a pretty good measure of how much money is needed to develop it to TRL-6.

They will certainly be trying to identify the key feasibility issues and the testing requirements for that concept and this is the primary output that we expect from this panel. They will also be addressing integration issues.

NASA Technology readiness levels are defined in Figure 18. Again, this project is intended to go through Technology Readiness Level-6, which is a system demonstrated in a simulated environment, including lifetime, performance, and system interactions. Level-7 is a flight test of that qualified system, so we are trying to determine what needs to be done to get to this point and how much it will cost. You can see the intermediate levels that get us there.

The reactor technology panel evaluation (Figure 19) is very similar to the propulsion panel, in that they will be assessing technical risk and trying to determine where that concept is on the technical readiness level scale. The same kinds of factors will be considered, but primarily inside the reactor, as opposed to outside the reactor in the other components of the propulsion system. The same scoring system is used.

The Advanced Development Planning panel (Figure 20) has the tough part; they have to figure out how much this is all going to cost. This really is a tough one, because the numbers that we have seen so far are all over, and it's pretty much a guessing game. As a first cut, we have asked the CFP's to try to come up with estimates.

Stan Borowski will talk about an initial estimate for the baseline system and we'll try to make our comparisons to that; if it looks like a concept is going to cost more, or a concept is going to cost less, and so forth. The factors that this panel will be considering, are the technology readiness level, the key testing, key feasibility issues, and the testing requirements, the verification issues, safety performance, how we do the simulation, and how we do the testing. A big part of the cost is certainly going to be wrapped up in facilities. Last, but not least, they will develop an overall estimated development cost for that system.

The safety panel, as mentioned (Figure 21), is distributed among the other panels and will be addressing hazard identification and mitigation, safety verification issues, launch safety, inherent control and stability, system refurbishment and disposal (which is certainly an important aspect), orbital assembly, and startup considerations, crew radiation protection (which will be a necessity), redundancy, reliability, and so forth. Also, any other safety issues that need to be considered.

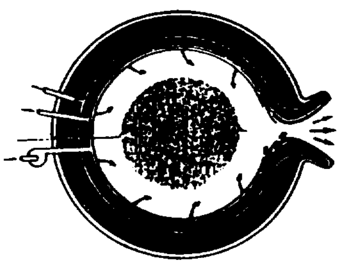
Finally, after we get through with the workshops (Figure 22), the technology review panels or (some smaller subgroup of those technology review panels) will get together to try to clarify some of the issues that have been identified for each of these concepts, and for the nuclear thermal propulsion technology as a whole, and to try to verify some claims that are made by the advocates. We will then do a collation of the written evaluations, and maybe do some simple calculations if that's appropriate. Finally, we will prepare recommendations that will go to the steering committee in the September time period. There will be a workshop proceedings published. And we do intend to provide some feedback to the concept focal points after the steering committee has met.

NASA – Lewis Research Center

WORKSHOP OVERVIEW

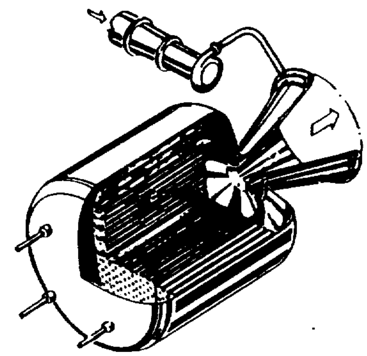
by John S. Clark
Workshop Chairman

NUCLEAR THERMAL PROPULSION WORKSHOP



JULY 10 – 12, 1990

CLEVELAND, OHIO



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NPWS1/7-5-90/JSC

Figure 1

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NASA/DOE/DOD

NUCLEAR THERMAL PROPULSION WORKSHOP

STATEMENT OF PURPOSE:

NASA is planning an Exploration Technology Program as part of the Space Exploration Initiative to return U.S. astronauts to the moon, conduct intensive robotic explorations of the moon and Mars, and to conduct a piloted mission to Mars by 2019.

Nuclear Propulsion is one of the key technology thrusts for the human mission to Mars. This workshop will address NTP tech–nologies; a similar workshop was hosted earlier by JPL for NEP technologies.

The purpose of the workshops is to assess the state of the art of nuclear propulsion concepts, assess the potential benefits of the concepts for the mission to Mars, identify critical, enabling technologies, lay–out (first order) technology development plans including facility requirements, and estimate the cost of developing these technologies to "flight–ready" status. The output from the workshops will serve as a data base for nuclear propulsion project planning.

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NPWS2/7-8-90JSC

Figure 2

NASA LEWIS RESEARCH CENTER

JULY 10, 1990

JOINT NASA/DOE/DoD
NUCLEAR PROPULSION WORKSHOP STEERING COMMITTEE

Members	Organ.:	Loc.:	Responsibilities:
BENNETT,GARY L.	NASA	RP	CHAIRMAN
WALQUIST,EARL J.	DOE	NP-50	
LENARD,ROGER LT.COL.	DoD	SDIO	
MILLER,THOMAS J.	NASA	LERC	EXEC. SEC.
Ex Officio Members:			
VERGA,RICHARD	DOD	SDIO	PROPULSION
BURICK,RICHARD J.	DOE	LANL	NUCLEAR SYSTEMS
COOPER, ROY	DOE	ORNL	NUCLEAR FUELS
MARTINELL,JOHN	DOE	INEL	NUCLEAR SYSTEMS
WALKER,JACK V.	DOE	SNL	NUCLEAR/SAFETY
WIDRIG,DICK	DOE	PNL	SPACE ENERGY SYSTEMS
CHANG-DIAZ, FRANKLIN	NASA	JSC	ASTRONAUT
KELLY,JIM	NASA	JPL	SPACE SYSTEMS
McDONOUGH, GEORGE	NASA	MSFC	DIR.-SCI & ENGR.
WEYERS,VERN	NASA	LERC	DIR,SPACE FLIGHT SYS.
Workshop Chairmen:			
BARNETT,JOHN	NASA	JPL	NEP WORKSHOP
CLARK,JOHN S.	NASA	LERC	NTP WORKSHOP

NUCLEAR PROPULSION PROJECT

Figure 3

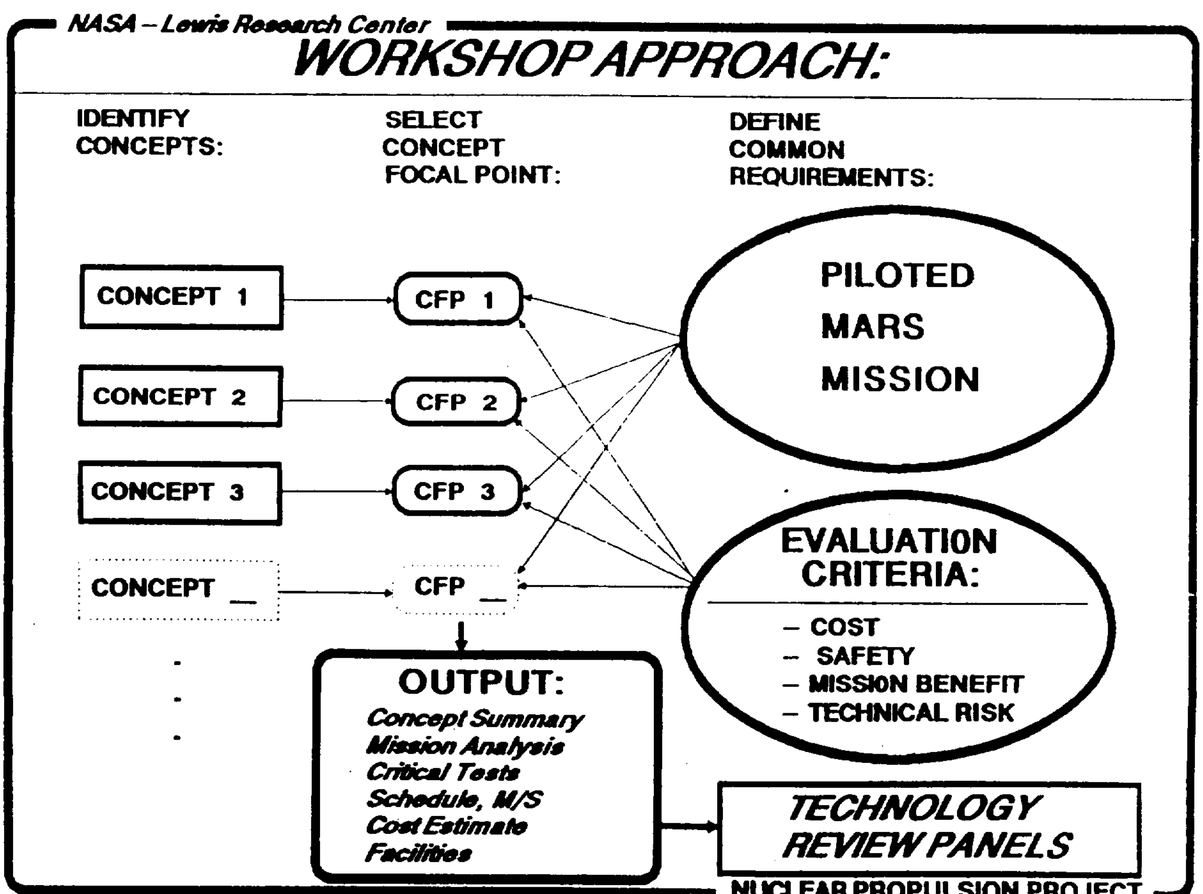

Figure 4

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NTP WORKSHOP MODUS OPERANDI

SUMMARY OF CONCEPTS

TUESDAY: ALL DAY – PLENARY SESSION

WEDNESDAY: UNTIL 9:15 – " "

PARALLEL WORKING PANELS

WEDNESDAY: 9:30 – 5:00

THURSDAY: 8:00 – 10:30 am

FEEDBACK FROM PANELS

THURSDAY: 1:00 – 3:30 pm

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Figure 5

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SPECIAL INFORMATION PRESENTATIONS:

TITLE:	ORG:	PRESENTER:
Tuesday:		
NTP BASELINE DESIGN	LeRC	STAN BOROWSKI
NERVA UPGRADE	ROCKETDYNE	STAN GUNN
DUAL MODE CONCEPTS	CONSULTANT	PRESTON LAYTON
NATL SPACE COUNCIL-REMARKS		PETER WORDEN
SSF TO SEI	NASA-LaRC	BRIAN PRITCHARD
Wednesday:		
UPDATED NERVA TRADE	ROCKETDYNE	MIKE NORTH
NTR MISSION APPLIC.	BOEING	BEN DONAHUE
PROPULSION SYS. NEED	ROCKETDYNE	STAN GUNN
NUCLEAR FUELS STATU	ORNL	ROY COOPER
REACTOR MATERIALS	MSFC	BILL EMRICH
SYSTEM TESTING ISSUE	SVERDRUP	DARRELL BALDWIN
NUCLEAR SAFETY	INEL	DAVE BUDEN
Thursday:		
QUICK TRIPS TO MARS	BOEING	DICK HORNUNG
DISPOSAL METHODS	SAIC	ALAN FRIEDLANDER
SAFETY ISSUES	LeRC	BOB ROHAL
FEEDBACK FROM PANELS		PANEL CHAIRMEN

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Figure 6

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CONCEPT FOCAL POINTS: NTP WORKSHOP

Solid Core:		
PIERCE,BILL	WESTINGHOUSE	NERVA DER. - ENABLER II
RAMSTHALER,JACK	DOE INEL	LOW PRESSURE CORE
LUDEWIG,HANS	DOE BNL	PBR
KRUGER,GORDON	GE	CERMET
DAHLBERG,RICHARD	GA	PULSED NUCLEAR
ZUBRIN,ROBERT	MARTIN-MARR.	NIMF
HARDY,DICK	ROCKWELL INTL	WIRE CORE
KIRK,BILL	DOE LANL	ADV. DUMBO
EL-GENK, MOHAMED	SAIC	PELLET BED
WRIGHT,STEVE	DOE SNL	FOIL REACTOR
Liquid Core:		
LUDEWIG,HANS	DOE BNL	LIQUID ANNULUS
ANGHAIE,SAMIM	U. FLORIDA	LIQUID CORE
Gaseous Core:		
RAGSDALE,BOB	NASA LERC	OPEN CYCLE A
LATHAM,TOM	UTRC	LITE BULB - GASEOUS CORE
DIAZ,NILS	U. FLORIDA	OPEN CYCLE B
NTP/NEP Hybrids:		
REID, BRUCE	DOE PNL	NTP/NEP HYBRIDS

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Figure 7

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Technology Review Panels: (Both NEP and NTP Workshops)

Mission Analysis:			
WICKENHEISER,TIM	NASA	LERC	PANEL CHAIR
SAWYER,BUZZ	NASA	HQ/QS	CREW SAFETY
DANDINI,VINCE	DOE	SNL	NUCLEAR SAFETY
PERKINS,DAVE	DOD	AFAL	PROPULSION SYSTEMS
COOMES,ED	DOE	PNL	POWER SYSTEMS
AUSTIN,GENE	NASA	MSFC	SPACE TRANS. & EXPLOR.
EVANS, DALLAS	NASA	JSC	LUNAR/MARS EXPLORATION
GEORGE,JEFF	NASA	LERC	NEP SYSTEMS ENGRG
GILLAND,JIM	NASA	LERC	NEP STUDIES, THRUSTER TECH.
HACK,KURT	NASA	LERC	TRAJECTORY ANALYSIS
SAUER,CARL	NASA	JPL	TRAJECTORY ANALYSIS
SUMRALL,PHIL	NASA	MSFC	SPACE EXPLORATION
STANCATI,MIKE	SAIC	ILL	EXEC.SEC.

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Figure 8

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Propulsion:			
HANNUM,NED	NASA	LERC	PANEL CHAIR
STANLEY, MARLAND	DOE	INEL	SAFETY
ERCEGOVIC,DAVE	NASA	LERC	SAFETY ASSURANCE
MCDANIEL,PAT	DOD	AFST	SNL-PBR
SCHMIDT, WAYNE	DOD	AFAL	NEP
SULLIVAN,GREG	DOD	SDIO	NT-PBR
GERSTEIN,NORM	DOE	HQ	FORMER NERVA
JOHNSON,BEN	DOE	PNL	INTEGRATION
MERRIGAN,MICHAEL A.	DOE	LANL	HEAT PIPE/HEAT TRANSFER
SCHOENBERG,KURT F.	DOE	LANL	PLASMA PHYSICS
BARNETT,JOHN	NASA	JPL	PROPULSION SYSTEMS
BOROWSKI,STAN	NASA	LERC	NUCLEAR SYSTEMS,EX SEC
CALAGEROUS,JIM	NASA	LERC	HEAT REJECTION
DUDENHOEFER,JIM	NASA	LERC	POWER SYSTEMS
NAININGER,JOE	NASA	LERC	POWER CONV. SYS.
RAGSDALE,BOB	NASA	LERC	GAS CORE
SOVEY,JIM	NASA	LERC	NEP
WINTER,JERRY	NASA	LERC	CSTI SYSTEMS
GERRISH, HAROLD	NASA	MSFC	PROPULSION

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Figure 9

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Reactor:			
DEARIEN,JOHN	DOE	INEL	MMW - PANEL CHAIR
LEE,JIM	DOD	SDIO	SAFETY-MMW
GALLUP,DON	DOE	SNL	REACTOR CONCEPTS,SAFETY
NIEDERAUER,GEORGE	DOE	LANL	SAFETY SP-100
REMP,KERRY	NASA	LERC	SAFETY
HELMS,IRA	CONS.		FORMER NERVA
BHATTACHARYYA,SAM	DOE	ANL	FUEL DEV.
MATTHEWS,R.BRUCE	DOE	LANL	FUEL DEV.
OLSEN,CHUCK	DOE	INEL	FUELS
POWELL,JIM	DOE	BNL	FUELS DEV.
RANKEN,WM.A.	DOE	LANL	THERMIONICS
WALTER,CARL	DOE	LLL	FUELS
BLOOMFIELD,HARVEY	NASA	LERC	SP-100, EXEC. SEC.
EMRICH,BILL	NASA	MSFC	PROPULSION SYS. DESIGN
MONDT,JACK	NASA	JPL	SP-100
SMITH,JOHN M.	NASA	LERC	SP-100
WHITAKER,ANN	NASA	MSFC	ENGR. PHYSICS
KLEIN,ANDY	OREGON	ST.	NUCLEAR ENGR.

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Figure 10

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Advanced Development Plan:			
HOWE,STEVE	DOE	LANL	PANEL CHAIR
ECKART,TED	CONS	AF	LAUNCH SAFETY,VANDENBERG
ALLEN, GEORGE	DOE	SNL	PROJ.MANAGE.,SAFETY
BOHL,DICK	DOE	LANL	SAFETY
BUDEN,DAVE	DOE	INEL	SAFETY, NERVA
KATO,WALTER	DOE	BNL	SAFETY
MARSHALL,AL	DOE	NP-50	SAFETY
RICE,JOHN	DOE	INEL	MMW-SAFETY
ROHAL,BOB	NASA	LERC	SAFETY
WARREN,JOHN	DOE	NP-50	MMW, NUCLEAR SYSTEMS
KIRK,BILL	DOE	LANL	NUCLEAR SYSTEMS,TESTING
BALDWIN,DARRELL	NASA	LERC	FACILITIES, EXEC. SEC.
BRANTLEY,WHIT	NASA	MSFC	PRELIM. DESIGN
BYERS,DAVID	NASA	LERC	NEP TECHNOLOGY
MARRIOTT,AL	NASA	JPL	SP-100
MILLER,TOM	NASA	LERC	NP PROJECT MANAGER
RICHMOND,BOB	NASA	MSFC	OAET R&T OFFICE
ROBBINS,RED	ANALYTICAL ENG		FORMER NERVA

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Figure 11

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Safety (Integrated with all Panels – Separate Report)			
SAWYER,BUZZ	NASA	HQ/QS	CREW SAFETY,PANEL CHAIR
ECKART,TED	CONS	AF	LAUNCH SAFETY,VANDENBERG
LEE,JIM	DOD	SDIO	SAFETY-MMW
ALLEN,GEORGE	DOE	SNL	NUCLEAR SAFETY
BOHL,DICK	DOE	LANL	SAFETY
BUDEN,DAVE	DOE	INEL	SAFETY, NERVA
DANDINI,VINCE	DOE	SNL	NUCLEAR SAFETY
GALLUP,DON	DOE	SNL	REACTOR CONCEPTS,SAFETY
KATO,WALTER	DOE	BNL	SAFETY
MARSHALL,AL	DOE	NP-50	SAFETY
NIEDERAUER,GEORGE	DOE	LANL	SAFETY SP-100
RICE,JOHN	DOE	INEL	MMW-SAFETY
STANLEY, MARLAND	DOE	INEL	SAFETY,EXEC.SEC.
ERCEGOVIC,DAVE	NASA	LERC	SAFETY ASSURANCE
REMP,KERRY	NASA	LERC	SAFETY
ROHAL,BOB	NASA	LERC	MISSION SAFETY

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Figure 12

EXPECTED OUTPUT FROM WORKSHOPS:

- FOR EACH CONCEPT:
  - CRITICAL TEST REQUIREMENTS
  - SAFETY ISSUES IDENTIFIED
  - FACILITY REQUIREMENTS IDENTIFIED
- FIRST – ORDER COMPARISON:
  - MISSION BENEFIT
  - TECHNICAL RISK
  - DEVELOPMENT COST TO TRL – 6

Figure 13

ASSESSMENT PROCEDURE:

PANEL:	*CRITERIA:*
MISSION ANALYSIS	MISSION BENEFIT
PROPULSION	TECHNICAL RISK
REACTOR	TECHNICAL RISK
ADVANCED DEVEL. PLANS	DEVELOPMENT COST
SAFETY	SAFETY

OUTPUT:

- → WRITTEN NARRATIVE, STRENGTHS/WEAKNESSES
- → RELATIVE RANKING – COMPARISON TO BASELINE

NPASSESS / 7-8-90 / JBC

Figure 14

NASA/DOE/DOD NUCLEAR THERMAL PROPULSION WORKSHOP

EVALUATION WORKSHEET

SESSION (PANEL NAME) ____________

EVALUATOR ____________

EVALUATOR PHONE NUMBER ____________ DATE ____________

CONCEPT ____________

PRESENTER (CFP) ____________

GENERAL COMMENTS ____________

CONCEPT STRENGTHS ____________

CONCEPT WEAKNESSES ____________

DESIRED CLARIFICATION OR SUBSTANTIATION ____________

Figure 15

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MISSION ANALYSIS PANEL

CONCEPT EVALUATION CRITERIA: MISSION BENEFIT

FACTORS:

1. IMLEO OR TRIP – TIME
2. SPECIFIC IMPULSE
2. INHERENT MISSION SAFETY/OPERATIONS
   - LAUNCH
   - ASSEMBLY
   - REUSEABILITY
   - DISPOSAL
   - etc.
4. COMMONALITY (OTHER MISSIONS)
5. AVAILABILITY IN 2006 ?
6. INHERENT RELIABILITY (COMPLEXITY)

SCORES:

1 PERFORMANCE MUCH LESS THAN BASELINE SYSTEM

2 PERFORMANCE LESS THAN BASELINE

3 SAME PERFORMANCE AS BASELINE

4 EXCEEDS THE PERFORMANCE OF THE BASELINE SYSTEM

5 PERFORMANCE SIGNIFICANTLY EXCEEDS BASELINE SYSTEM

CONFIDENCE IN SCORE:

LOW MEDIUM HIGH

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Figure 16

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PROPULSION TECHNOLOGY PANEL

CONCEPT EVALUATION CRITERIA: TECHNICAL RISK

TECHNOLOGY READINESS LEVEL:

CFP SELF – RATING: ________ (1 – 6)

EVALUATOR'S RATING: ________ (1 – 6)

FACTORS:

1. CONCEPT MATURITY (TRL)
   - FEASIBILITY DEMONSTRATED
   - CONCEPTS DEMONSTRATED
   - SCALING DEMOS/ RULES
   - SYSTEM DEMONSTRATIONS
2. KEY FEASIBILITY ISSUES/ TESTS REQ'D
3. FACILITY REQUIREMENTS
   - EXISTING / MODS REQ'D
   - NEW
4. INTEGRATION
   - PROPELLANT TANKS, LINES
   - TURBOPUMPS
   - NOZZLES
   - REFLECTORS, CONTROLS
   - REACTOR, SUPT. STRUCTURE
   - THERMAL MANAGEMENT
5. OTHERS

SCORES:

5 – MUCH LESS RISK THAN BASELINE

4 – LESS RISK THAN BASELINE

3 – SAME RISK AS BASELINE

2 – MORE TECHNICAL RISK THAN BASELINE SYSTEM

1 – MUCH MORE RISK THAN THE BASELINE SYSTEM

CONFIDENCE IN SCORE:

LOW MEDIUM HIGH

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NE NLP/7-8-90USC

Figure 17

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TECHNOLOGY READINESS LEVEL:

LEVEL 1: BASIC PRINCIPLES OBSERVED AND REPORTED

LEVEL 2: CONCEPT FORMULATED INTO APPLICATION

LEVEL 3: PROOF – OF – CONCEPT PROVEN

LEVEL 4: COMPONENT/BREADBOARD VALIDATION IN LAB

LEVEL 5: COMPONENT/BREADBORD DEMO IN RELEVANT ENVIRONMENT

LEVEL 6: SYSTEM VALIDATION MODEL DEMONSTRATED IN SIMULATED ENVIRONMENT, INCLUDING LIFE, PERFORMANCE,AND SYSTEM INTERACTIONS

LEVEL 7: FLIGHT TEST OF A QUALIFIED SYSTEM

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TRLEVEL/7-8-90USC

Figure 18

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REACTOR TECHNOLOGY PANEL

CONCEPT EVALUATION CRITERIA: TECHNICAL RISK

TECHNOLOGY READINESS LEVEL:

CFP SELF – RATING: ________ (1 – 6)

EVALUATOR'S RATING: ________ (1 – 6)

FACTORS:

1. CONCEPT MATURITY (TRL)
   - FEASIBILITY DEMONSTRATED
   - NUCLEAR FURNACE
   - REACTOR TESTS/VERIF.
   - MODELS VERIFIED
2. KEY FEASIBILITY ISSUES/ TESTS REQ'D
3. FACILITY REQUIREMENTS
   - EXISTING / MODS REQ'D
   - NEW
4. PROPULSION SYSTEM INTEGRATION
   - FAILURE MODES
   - THERMAL MANAGEMENT
   - CONTROLS/INSTRUMENT.
5. VEHICLE OPERATIONS/ SAFETY
   - ORBITAL ASSEMBLY
   - LAUNCH/REENTRY/DISPOSAL
   - RESTART/COMMONALITY

SCORES:

5 – MUCH LESS RISK THAN BASELINE

4 – LESS RISK THAN BASELINE

3 – SAME RISK AS BASELINE

2 – MORE TECHNICAL RISK THAN BASELINE SYSTEM

1 – MUCH MORE RISK THAN THE BASELINE SYSTEM

CONFIDENCE IN SCORE:

LOW MEDIUM HIGH

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Figure 19

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ADVANCED DEVELOPMENT PLAN PANEL

CONCEPT EVALUATION CRITERIA: DEVELOPMENT COST

CFP ESTIMATED COST, ________ , \$M

EVALUATOR'S ESTIMATED COST, ________ , \$M

FACTORS:

1. CONCEPT MATURITY (TRL 1 – 6)
   - FEASIBILITY DEMONSTRATED
   - COMPONENT VALIDATION
   - SYSTEM BREADBOARD DEMO.
   - SYSTEM VALIDATED
2. KEY FEASIBILITY ISSUES/ TESTS REQ'D
3. VERIFICATION ISSUES (SAFETY/PERF.)
   - SIMULATION
   - TESTING
4. FACILITY REQUIREMENTS
   - EXISTING / MODS REQ'D
   - NEW
5. ESTIMATED DEVELOPMENT COST (COMPARED TO BASELINE SYSTEM)

SCORES:

5 – MUCH LESS COST THAN BASELINE

4 – LESS COST THAN BASELINE

3 – SAME COST AS BASELINE

2 – MORE COST THAN BASELINE SYSTEM

1 – MUCH MORE COST THAN THE BASELINE SYSTEM

CONFIDENCE IN SCORE:

LOW MEDIUM HIGH

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Figure 20

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SAFETY PANEL

CONCEPT EVALUATION CRITERIA: SAFETY

FACTORS:

1. HAZARD IDENTIFICATION & MITIGATION
2. SAFETY VERIFICATION ISSUES
3. LAUNCH SAFETY COMPATIBILITY
4. INHERENT CONTROL/ STABILITY
5. SYSTEM REFURBISHMENT/ DISPOSAL
6. ORBITAL ASSEMBLY / STARTUP
7. CREW RADIATION PROTECTION
8. REDUNDANCY / RELIABILITY
9. ETC.

SCORES:

1 – UNACCEPTABLE

2 – NOT AS SAFE AS BASELINE SYSTEM

3 – ABOUT THE SAME AS BASELINE

4 – SAFER THAN BASELINE

5 – MUCH SAFER THAN BASELINE

CONFIDENCE IN SCORE:

LOW MEDIUM HIGH

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Figure 21

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AFTER THE WORKSHOPS:

TECHNOLOGY REVIEW PANEL / (SUB – GROUPS)

TECHNICAL INPUT:

CLARIFY ISSUES
VERIFY CLAIMS
COLLATE EVALUATIONS
SAMPLE CALCS.
QUESTIONS TO CFP
RECOMMENDATIONS

NASA

DOE

DOD

STEERING COMMITTEE
WORKSHOP PROCEEDINGS
FEEDBACK TO CFP'S

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Figure 22