ADVANCED PROPULSION CONCEPTS

Presented to the
Integrated Technology Plan External Review

JPL

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ADVANCED PROPULSION CONCEPTS

OBJECTIVES

PROGRAMMATIC

ESTABLISH THE FEASIBILITY OF PROPULSION TECHNOLOGIES FOR VASTLY EXPANDED SPACE ACTIVITY

TECHNICAL

REVOLUTIONARY PERFORMANCE SOUGHT:

- ~1kg/kW specific mass
- Specific impulse tailored to mission requirements
- Ability to use in-situ resources
- Round-trips to Mars in months
- Round-trips to outer planets in 1 to 2 years
- The capability for robotic missions beyond the solar system

SCHEDULE

1991 COMPLETE FIRST ECR PLASMA ENGINE THEORY
1992 MEASURE CARBON-60 ION PROPERTIES
1992 TEST 25-kW ELECTRODELESS ROCKET
1993 TEST SUPERSONICALLY-HEATED μWAVE ROCKET
1994 RESOLVE KEY PLASMA PLUME PHYSICS ISSUES
1995 TEST SUSTAINED MW-CLASS PLASMA ROCKET
1996 PROVE LIFE/PERFORMANCE OF C-60 ION ENGINE
1996 SUSTAIN CONFINEMENT OF ATOMIC HYDROGEN
1997 APPLY MICRO-FISSION DEMONSTRATION TO ICAN FISSION/FUSION PROPULSION FEASIBLITY ISSUES
004+ LABORATORY SCALE ATOMIC HYDROGEN ROCKET
004+ 10 MW-CLASS PLASMA ENGINE & S.S. μWAVE ROCKET
004+ ICAN SYSTEM PROOF-OF-CONCEPT
004+ 100 kW GROUND-TO-SPACE PHASE CONJUGATE BEAM

RESOURCES ($M)

	CURRENT	3X	STRATEGIC
1991	1.2	1.2	1.2
1992	1.4	1.4	1.4
1993	1.5	3.2	3.5
1994	1.5	4.0	4.0
1995	1.6	4.7	4.7
1996	1.6	5.0	5.0
1997	1.7	6.0	6.0

PARTICIPANTS

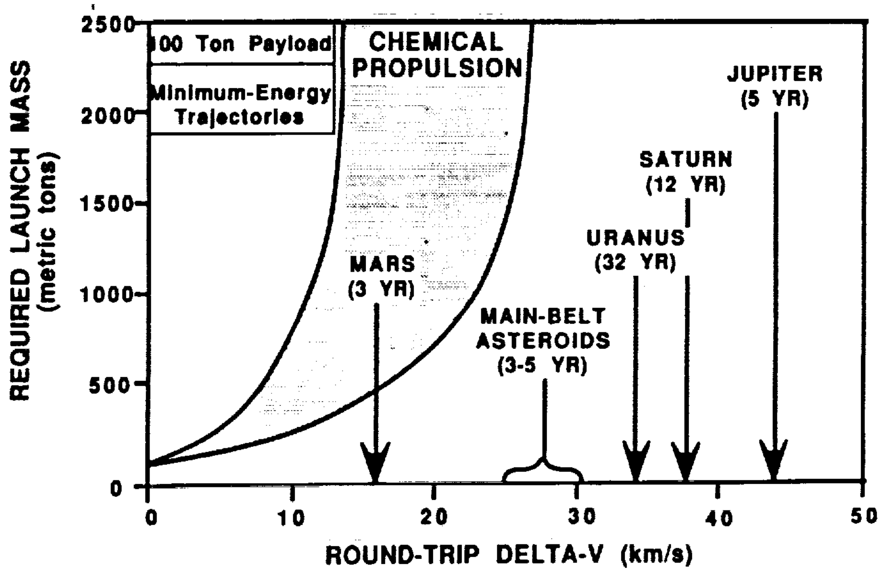
JPL

- ECR PLASMA ENGINE
- C-60 MOLECULAR ION THRUSTER
- SUPERSONICALLY-HEATED MICROWAVE ROCKET
- TANDEM MIRROR PLASMA ROCKET
- COMPUTATIONAL PLASMA PHYSICS
- MICRO FISSION/FUSION (ICAN) PROPULSION
- PLASMA PLUME PHYSICS RESEARCH
- SYSTEMS ANALYSIS

LeRC

- MW-CLASS PLASMA ROCKET
- E-M FIELD/PLASMA INTERACTIONS
- ELECTRODELESS ROCKETS
- BEAMED ENERGY FOR PROPULSION
- ATOMIC HYDROGEN

ADVANCED PROPULSION CONCEPTS
The Limits of Chemical Propulsion



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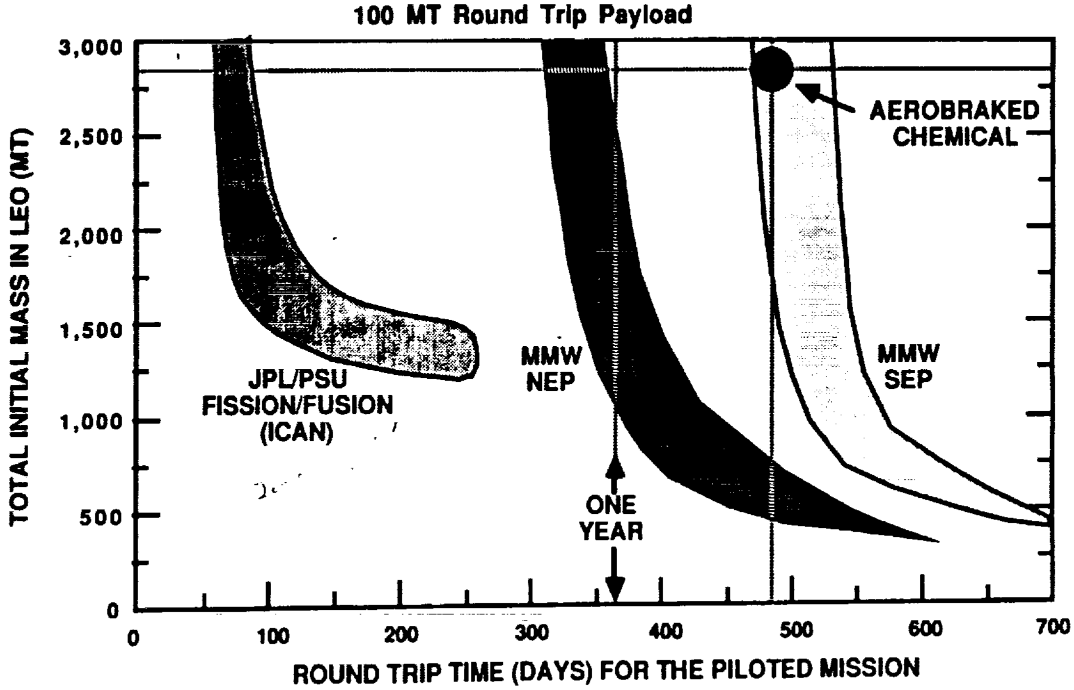
ADVANCED PROPULSION CONCEPTS

MAJOR BENEFITS FOR FUTURE NASA MISSIONS

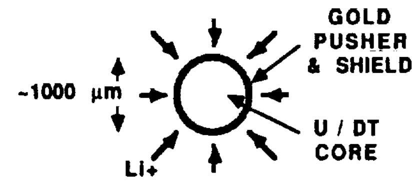
100 MT Round Trip Payload



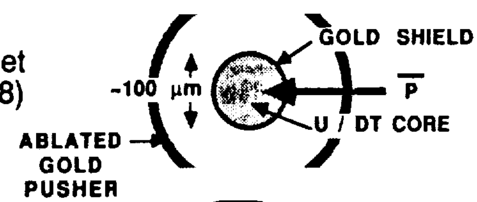
PENN STATE ION-COMPRESSED ANTIMATTER-CATALYZED NUCLEAR (ICAN) PROPULSION

CONCEPT DESCRIPTION

- Uranium (or Pu) enriched DT (or D-He3) pellet is compressed using a megajoule-class light ion (Li) driver

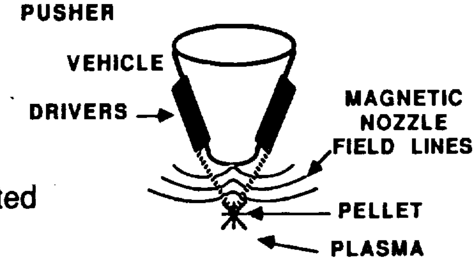


- At the time of peak compression, the target is bombarded with a small number (~10^8) of antiprotons to catalyze fission



- The fission energy release triggers a high-efficiency fusion burn to heat the propellant

- The resulting expanding plasma is deflected by a magnetic nozzle to produce thrust



RECENT RESULTS FROM PENN STATE FISSION/FUSION (ICAN) WORK

- THE TECHNOLOGY FOR A 10 GW SYSTEM MAY BE FEASIBLE IN 2010 TIME FRAME ...GIVEN ADEQUATE RESOURCES

- ANTIPROTON QUANTITIES REQUIRED ACHIEVABLE

  - 10^8 ANTIPROTONS PER PELLET CAN BE PRODUCED NOW IN TEN MIN. AT CERN

  - SOLID ANTI-H2 STORAGE NOT NEEDED

- RADIATION FLUENCE MAY BE MUCH LOWER THAN FUSION PROPULSION

- ≈100 DAY ROUND-TRIP TO MARS

- AFOSR INITIATIVE TO DEMONSTRATE SCIENTIFIC FEASIBLITY OF MICRO-FISSION IN FIVE YEARS ($3.5M LEVERAGED THUS-FAR)

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PENN STATE FISSION/FUSION (ICAN) WORK
Program Goals

THIS YEAR

DEVELOPED MICRO-FISSION AND FISSION/FUSION CONCEPTS THROUGH DETAILED PELLET MODELING

CONVINCED AFOSR TO ESTABLISH INITITIVE TO PROVE SCIENTIFIC FEASSIBLITY IN ≈5 years

NEXT YEAR

CONTINUE THEORETICAL RESEARCH TO ADDRESS MINIMIZING RADIATION FLUENCE FROM PROPULSION SYSTEM (D-HE3 FUEL)

IMPROVED MODELS OF UP-COMING EXPERIMENTS AT SHIVA STAR

DETAILED EXPERIMENTAL DESIGN AND PLANNING

FUTURE YEARS

ADDRESS CRITICAL TECHNOLOGIES IN SUPPORTING SUBSYSTEMS

CONTINUE TO DEVELOP CONCEPT TO ESTABLISH FEASIBILITY FOR FLIGHT IN 2010-2020 TIME FRAME

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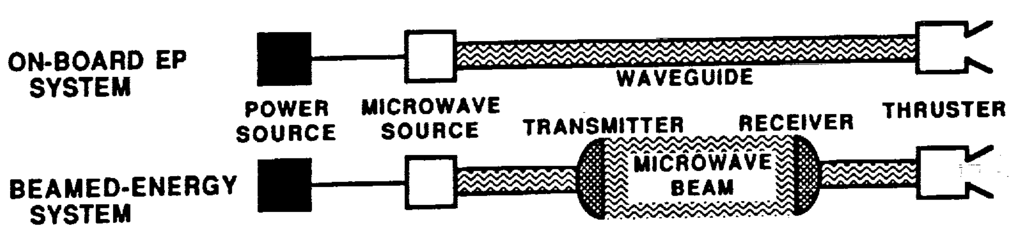
ELECTRODELESS ELECTRIC PROPULSION THRUSTERS

- May dramatically improve EP thruster life by eliminating electrodes and their associated erosion
- Absorb microwave energy into propellant
  - Examples
    - Electron-Cyclotron Resonance Thruster (JPL)
    - Microwave Electrothernal Rockets (LeRC & JPL)
    - Variable-Isp Plasma Rocket (MIT)
- May be able to use extraterrestrial-produced propellants (e.g., O2)
- Can be used as an electric propulsion system (with on-board microwave source) or as a beamed-energy system (with a remote microwave transmitter)



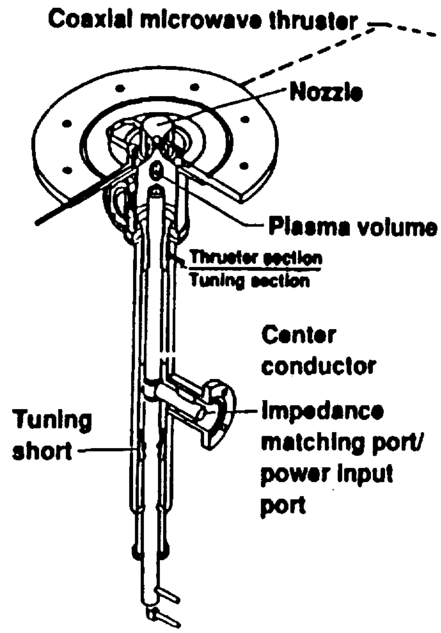
ATD AEROSPACE TECHNOLOGY DIRECTORATE

SPACE PROPULSION TECHNOLOGY DIVISION

NASA Lewis Research Center

ADVANCED PROPULSION CONCEPTS

ELECTRODESELESS ROCKETS- MICHIGAN STATE UNIVERSITY



The potential for high power absorption (>90%) into the propellant can be realized using external impedance matching with the coaxial microwave thruster

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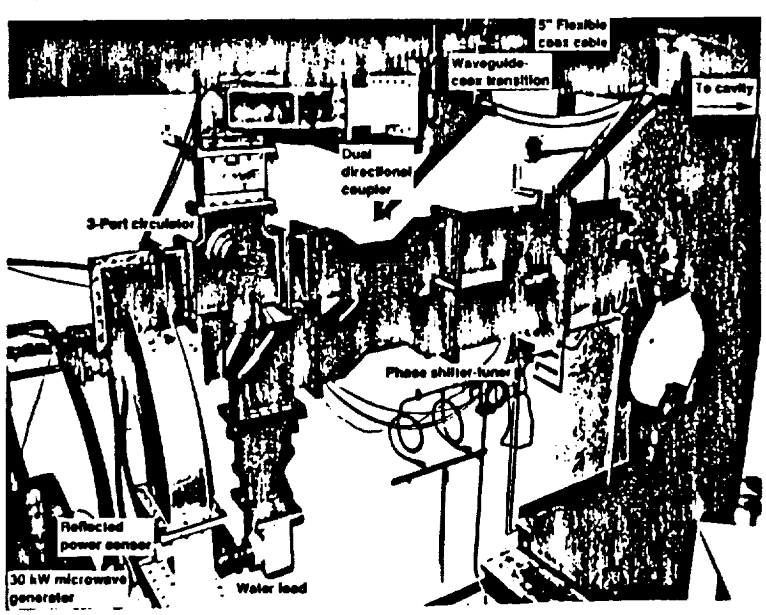
ADVANCED PROPULSION CONCEPTS

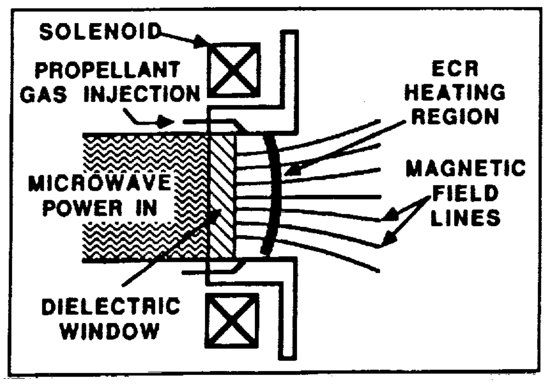
POWER CIRCUIT FOR ELECTRODELESS THRUSTER COMPLETED

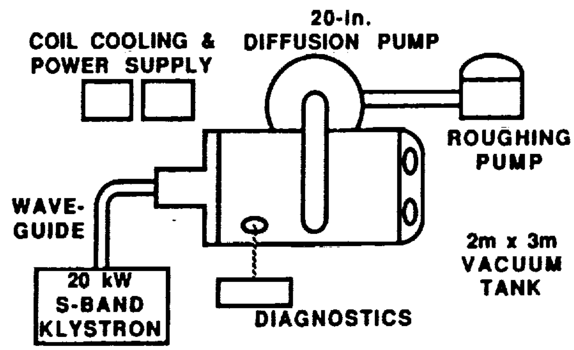


CD-90-51117

ELECTRON-CYCLOTRON RESONANCE (ECR) PLASMA ENGINE

- Recent Work
  - Quasi 1-D Plasma Model
  - Axisymmetric Magnetic Nozzle Model
  - Completed assembly of test facility and preliminary experiments
- Near-term plans
  - Optimize magnetic field configuration
  - Automate experimental facility
  - Improve theoretical models
- Future plans
  - Optimized devices
  - Higher power levels
  - Alternate propellants





ELECTRODELESS ELECTRIC THRUSTERS
Program Goals

THIS YEAR

COMPLETE ECR PLASMA ENGINE BASIC PHYSICS RESEARCH WITH GO/NO-GO DECISION

NEXT YEAR

TEST 25-kW ELECTRODELESS ROCKET CONCEPT

INITIATE DEVELOPMENT OF HIGH-EFFICIENCY AND/OR HIGH THRUST ECR DEVICE (CONTINGENT ON DECISION)

FUTURE YEARS

DEMONSTRATE APPLIED-FIELD ELECTRODELESS DEVICES AT HIGH SPECIFIC IMPULSES AND EFFICIENCIES

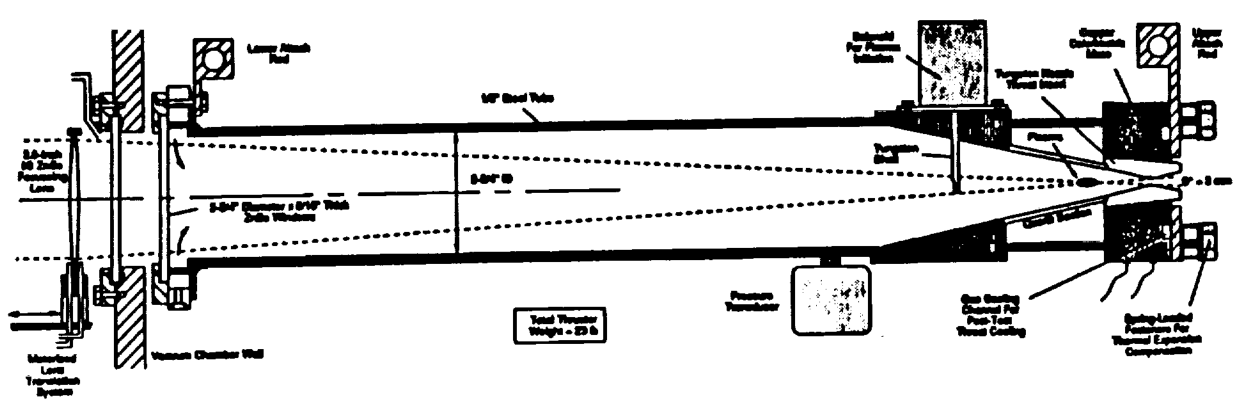
BEAMED ENERGY PROPULSION

- Improve propulsion system performance by removing the power source from the vehicle
  - Locate the source (laser) on ground or in orbit
- Various combinations of source, source location, and propulsion system possible
  - Near-visible vs microwave
  - Ground-based vs space-based transmitter
  - Direct (thermal) thruster vs indirect (beam -> electric) EP thruster
- All concepts limited by transmission capability
  - Atmospheric effects for ground-based lasers
  - Diffraction effects for long distances (probably)

Combustion Sciences, Inc.
Space Propulsion Division

Thruster Layout

- Specific Impulse = 600 - 700 sec
- Pressure = 1.0 atm
- Plasma Efficiency ≈ 35%
- Overall Efficiency ≈ 20%
- Mass Flow ≈ 0.1 g/sec
- Throat D* = 3 mm
- Thrust ≈ 0.5 N



SPACE PROPULSION TECHNOLOGY DIVISION

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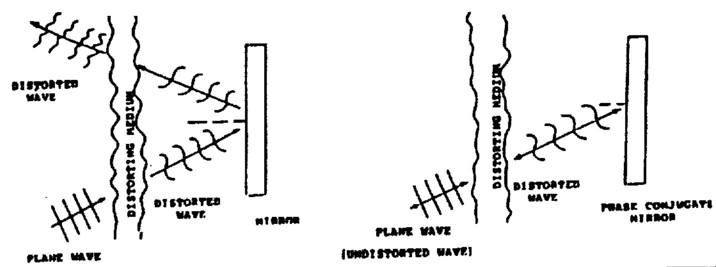
PHASE CONJUGATION

- ALTERNATIVE TO ADAPTIVE OPTICS
- NON-LINEAR OPTICAL EFFECT
  - "DYNAMIC HOLOGRAPHY"
  - EXACTLY REVERSES DIRECTION, PHASE OF INCIDENT BEAM
  - ELIMINATES EFFECTS OF DISTORTING MEDIUM



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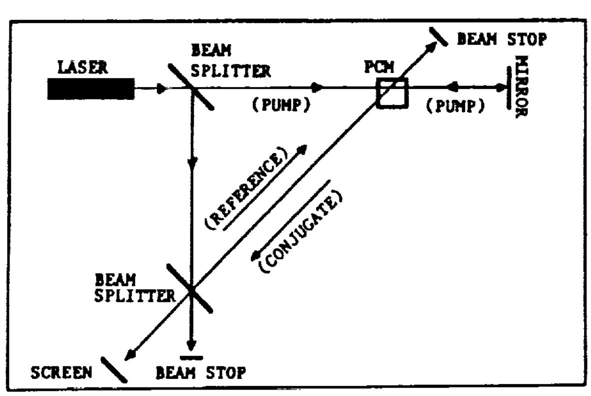
PHASE CONJUGATION

IN-HOUSE PHASE CONJUGATION EXPERIMENTS



ADVANCED PROPULSION CONCEPTS

BEAMED ENERGY PROPULSION
Program Goals

LASER ROCKET

BUILD & DIRECTLY TEST A 10 kW LASER ROCKET (AT U. of ILL.)

- ANCHOR THERMAL & PERFORMANCE MODLES
- DIRECTLY EVALUATE THRUST VS GEOMETRY & CONDITIONS

DESIGN AND FABRICATE A 100 kW LASER ROCKET

PHASE CONJUGATE OPTICS

CONTINUE IN-HOUSE LeRC PHASE CONJUGATION EXPERIMENTS

- 3,4 WAVE MIXING
- LOW POWER HeNe LASER
- BaTiO3 PHOTOREFRACTIVE CRYSTALS

WORK TOWARD 100 kW GROUND-TO-SPACE DEMONSTRATION

ADVANCED PROPULSION CONCEPTS

LeRC MULTIMEGAWATT PLASMA ROCKET PROGRAM

JOINT DOE-NASA PROGRAM INITIATED WITH LOS ALAMOS

- LEVERAGES FUSION REACTOR PROGRAM BY USING 100 MW SPHEROMAK TECHNOLOGY
- HAVE DEMONSTRATED OPERATION AT 10 MW
- WILL ESTABLISH POWER BALLANCE AND SCALING CHARACTERISTIC OF LARGE SCALE (0.5m) ROCKETS OPERATED WITH EXTERNAL MAGNETIC FIELDS

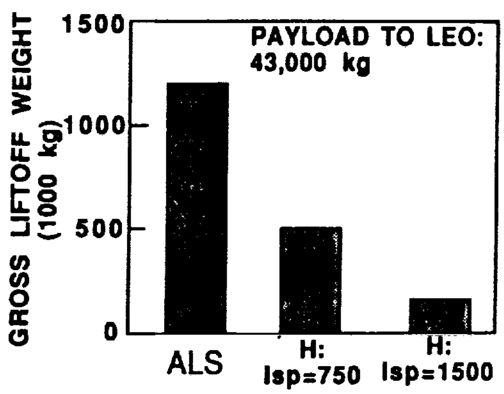
PROGRAM GOALS

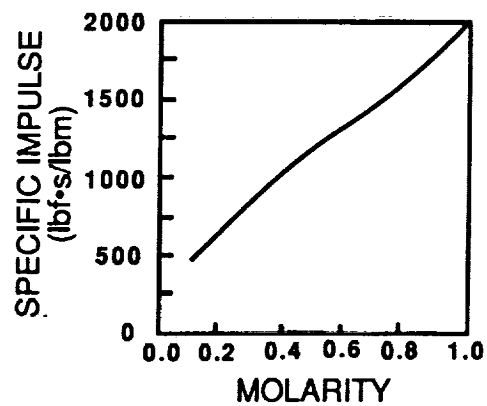
- 1995: DEMONSTRATE SUSTAINED MW-CLASS PLASMA ROCKET
- 1998-2003: DEMONSTRATE SUSTAINED 2 MW PLASMA ROCKET
- BEYOND 2004: DEMONSTRATE 10 MW PLASMA ROCKET

LeRC ATOMIC HYDROGEN ROCKET PROGRAM

CONCEPT:

FREE RADICAL ATOMIC HYDROGEN IS STORED IN A SOLID MATRIX OF MOLECULAR HYDROGEN UNDER HIGH MAGNETIC FIELD AND LOW CRYOGENIC TEMPERATURE





ADVANCED PROPULSION CONCEPTS

LeRC ATOMIC HYDROGEN ROCKET Program Goals

APPROACH

CONTRACT WORK AT LLNL, U. of HAWAII, AND OAK RIDGE

LeRC SYSTEMS ANALYSIS AND VEHICLE STUDIES

1995

IDENTIFY ATOMIC HYDROGEN CONFINEMENT TECHNIQUE

1996

DEMONSTRATE SUSTAINED CONFINEMENT

BEYOND 2004

TEST LABORATORY SCALE ATOMIC HYDROGEN ROCKET

SUPERSONICALLY-HEATED MICROWAVE ELECTROTHERMAL ROCKET

CONCEPT:

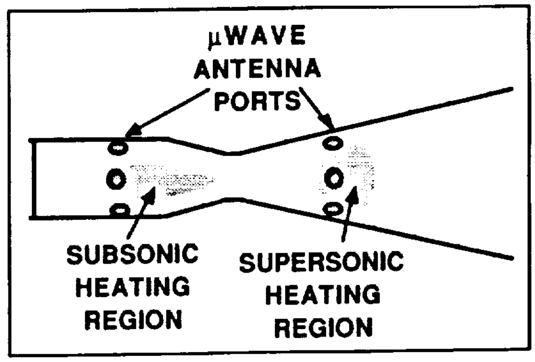
MICROWAVE ENERGY IS COUPLED TO A GAS IN SUPERSONIC FLOW DOWNSTREAM OF THE THROAT - A "MICROWAVE AFTERBURNER"

POTENTIAL BENEFITS:

MAY CIRCUMVENT HEATING LIMITS TO ROCKET PERFORMANCE
- 2X IN SPECIFIC IMPULSE
- 2X IN EFFICIENCY

HISTORY:

A QUALITATIVE EXTENSION OF LeRC, P.S.U., and M.S.U. MICROWAVE ROCKET RESEARCH



SUPERSONICALLY-HEATED µWAVE ROCKET
Program Goals

YEAR ONE

VERIFY THEORETICAL CONCEPT BENEFITS BY MODELING:
- SUPERSONIC HEATING REGION
- VISCOUS EFFECTS
- ENERGY TRANSFER KINETICS AND GAS EXPANSION

YEAR TWO

- MODIFY JPL APPARATUS TO DEMONSTRATE S.S. HEATING
- INVESTIGATE DIFFERING ANTENNA SCHEMES AND ENGINE PERFORMANCE

FUTURE YEARS

- DEVELOP FLIGHT-LIKE NEAR-TERM SYSTEMS
- DEVELOP ADVANCED CONCEPT ENGINES
- STUDY APPLICATION TO OTHER ROCKET SYSTEMS

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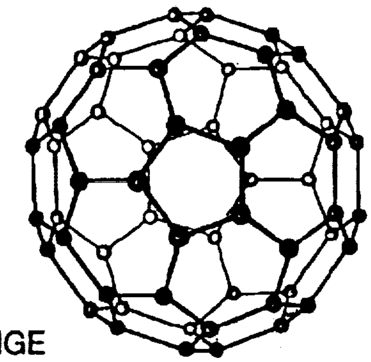
ADVANCED PROPULSION CONCEPTS

CARBON-60 ION PROPULSION

CONCEPT:

BUCKMINSTERFULLERENE IS SUBLIMATED, IONIZED AND ELECTROSTATICALLY ACCELERATED TO PRODUCE THRUST



POTENTIAL BENEFITS:

- FIRST CLUSTER PROPULSION CONCEPT TO PROMISE HIGH PROP. UTILIZATION, MONO-MASS DISTRIBUTION, MINIMAL FRAGMENTATION, LARGE ION MASS, AND LOW IONIZATION ENERGY
- HIGH EFFICIENCY EVEN IN 1000 - 3000 s RANGE
- DRAMATICALLY RELAXED GRID SPACING AND DISCHARGE CURRENT FOR ULTRA-HIGH-POWER ION ENGINES

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ADVANCED PROPULSION CONCEPTS

CARBON-60 ION PROPULSION
Program Goals

YEAR ONE

VERIFY THEORETICAL CONCEPT BENEFITS BY MEASURING:
- IONIZATION CROSS SECTIONS
- VAPOR PRESSURE CURVES
- FRAGMENTATION EFFECTS

YEAR TWO

ADDRESS PRACTICAL DEVELOPMENT ISSUES
- SELECT BEST IONIZATION/ACCELERATION SCHEMES
- MEASURE CHARGE-TO-MASS DISTRIBUTIONS
- INVESTIGATE CONDENSATION AND SPUTTERING

FUTURE YEARS

- DEVELOP FLIGHT-LIKE NEAR-TERM SYSTEMS
- DEVELOP ADVANCED CONCEPT ENGINES
- EXAMINE HIGHER-MASS CARBON CLUSTERS

JPL U.S. ADVANCED PROPULSION RESEARCH

JPL

- Mission Studies
- ECR Plasma Engine
- Carbon-60 Engine
- Supersonic µWave Rocket
- University Research
  - PSU - Fission/Fusion Hybrid
  - CIT
    - Magnetic Nozzles for ICF
    - Computational Plasma Physics
  - MIT - Tandem Mirror Plasma Engine
  - Brown U. - H2 Magnetic Lervitation

LeRC

- Magnetic Nozzles
- Microwave Thruster
- Beamed Energy Optics Analysis
- High-Energy Density Chemical Propellants
  - Metallized Propellants
- ET Resource Thrusters
  - O2/CO
- University Research
  - OSU - Magnetic Nozzles
  - U. Ill. - Laser Thruster
  - U. Hawaii - Atomic Hydrogen

Air Force

- Fusion
  - Dense Plasma Focus
  - Cluster Ion
- Field Propulsion Concepts
- Solar Thermal Propulsion Thruster
- High-Energy Density Propellants
  - Chemical
  - Antimatter

Others

- ET Propellant Production
  - Moon : JSC
  - Mars : U. of Arizona, Old Domin. U.
- Solar Sails
  - World Space Found.
- Mass Drivers
  - Coaxial : SSI
  - Rail Guns : SDIO
  - Ram Accel. : U. of Wash.
- Laser Propulsion
  - Lasers : SDIO, LLNL, LANL
  - Thrusters : U. of Tenn., RPI
- Fusion
  - U. of Illnois
  - AFOSR
  - LLNL
- Antimatter
  - LANL
  - Penn State U.

Note: Does not address fission research

ADVANCED PROPULSION CONCEPTS SUMMARY

TECHNICAL CHALLENGE:

STATE-OF-THE-ART AND EMERGING PROPULSION TECHNOLOGIES DO NOT MEET THE REQUIREMENTS FOR MANY AMBITIOUS 21st CENTURY SPACE MISSIONS. FOR EXAMPLE, BIOMEDICAL CONSIDERATIONS MAY RULE OUT TRIPS TO MARS WITH FLIGHT TIMES GREATER THAN ONE YEAR – HENCE APC MAY BE REQUIRED EVEN FOR SEI

TECHNOLOGY MANAGEMENT APPROACH:

- IN-HOUSE SYSTEMS STUDIES (BENFIT V.S. TECHNOLOGY NEEDS)
- IN-HOUSE PROOF-OF-CONCEPT RESEARCH (EXPERIMENTS AND THEORY)
- CONTRACTED RESEARCH (ESPECIALLY EXPERIMENTS AND THEORY AT UNIVERSITIES)

PAYOFF: REVOLUTIONIZE SPACE TRAVEL

- ROUND-TRIPS TO MARS IN A FEW MONTHS
- PILOTED ROUND-TRIPS TO OUTER PLANETS IN 1 TO 2 YEARS
- ROBOTIC MISSIONS BEYOND THE SOLAR SYSTEM

RATIONALE FOR AUGMENTATION:

- MAY BE THE MOST IMPORTANT TECHNOLOGIES FOR 21st CENTURY SPACE ACTIVITES
- CURRENT PROGRAM FUNDING IS SUBCRITICAL - 3x PLAN IS VITAL

RELATIONSHIP TO FOCUSED ACTIVITIES AND OTHER PROGRAMS:

- CONNECTIONS TO PROGRAMS SUCH AS SEI MADE VIA SYSTEMS STUDIES AND MEETINGS
- RESEARCH COMPONENT OF THIS PROGRAM STILL NEW
- HAS LEVERAGED SIGNIFICANT PROGRAMS FROM OTHER AGENCIES:

  i.e. JPL's SUPPORT OF ICAN AT PENN STATE RESULTED IN A $3.5M AFOSR INITIATIVE TO DEMONSTATE FEASIBILITY OF MICRO-FISSION

ADVANCED PROPULSION TECHNOLOGY

TITLE: ADVANCED HIGH THRUST EXPANDER CYCLE THRUST CHAMBER TECHNOLOGY

OBJECTIVE: INVESTIGATE AND VERIFY AT LARGE SCALE THE TECHNOLOGIES NEEDED TO ALLOW OPERATION OF AN O2/H2 EXPANDER CYCLE THRUST CHAMBER AT HIGH THRUST LEVELS

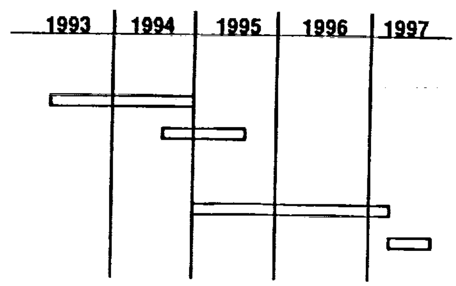
APPROACH: SUPPLIMENT EXPANDER CYCLE WORK TO EXPLORE ALTERNATE HEAT TRANSFER ENHANCEMENT APPROACHES FOR HIGH THRUST APPLICATIONS. PURSUE SUBSCALE INVESTIGATIONS TO CHARACTERIZE THE APPROACHES. SELECT THE MOST PROMISING FOR VERIFICATION AT LARGE SCALE. TESTING TO BE DONE AT THE MSFC TEST CELL 116.

FUNDING REQUIREMENT:	FY93	FY94	FY95	FY96	FY97
$K	500	1500	3000	3000	2500

SCHEDULE:

SUBSCALE
- DESIGN / FAB
- TEST

LARGE SCALE
- DESIGN / FAB
- TEST



APPLICATION: APPLICATIONS FOR HIGH THRUST EXPANDER CYCLE ENGINES INCLUDE UPPER STAGES, ORBIT TRANSFER, INTERPLANETARY TRANSFER VEHICLES

ADVANCED PROPULSION TECHNOLOGY

TITLE: LARGE SCALE PLATELET CHAMBER DEMONSTRATION

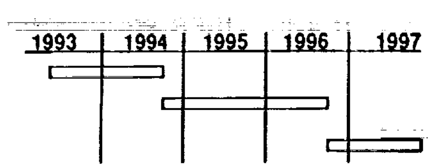
OBJECTIVE: VALIDATE FORMED PLATELET COOLING LINER CONSTRUCTION IN A LARGE SCALE COMBUSTION CHAMBER

APPROACH: SUPPLIMENT EXISTING WORK UNDER CONTRACT NAS8-37456 TO CONSTRUCT A LARGE SCALE THRUST CHAMBER AND TEST FIRE THE CHAMBER TO VERIFY THE PLATELET DESIGN APPLICATION. CHAMBER SIZE WILL BE BASED ON A DESIGN THAT IS COMPATIBLE WITH USING AN EXISTING HIGH THRUST METHANE INJECTOR (750KLB). THE TESTS WILL EMPLOY O2/H2 AT A THRUST LEVEL OF ABOUT 450 KLB. THE CHAMBER STRUCTURE WILL BE BASED ON EITHER CASTING TECHNOLOGY BEING DEVELOPED UNDER THE ADVANCED MAIN COMBUSTION CHAMBER ACTIVITY OR A GENERAL WORKHORSE CONSTRUCTION APPROACH. TESTING WILL BE CONDUCTED AT THE MSFC TEST CELL 116.

FUNDING REQUIREMENT:	FY93	FY94	FY95	FY96	FY97
$K	500	1000	1500	2000	500

SCHEDULE:

- DESIGN
- FABRICATION
- TEST



APPLICATION: APPLICATIONS FOR FORMED PLATELET CONSTRUCTION INCLUDE ANY ROCKET ENGINE NEW DEVELOPMENT OR EXISTING ENGINE MODIFICATION WHICH CAN BENEFIT FROM LOW HOT WALL TEMPERATURES IN THE RANGE OF 400°F TO 700°F.

TITLE: ADVANCED CAST HOT GAS MANIFOLD FOR HIGH PRESSURE PREBURNER CYCLE ENGINES

OBJECTIVE: DEMONSTRATE TECHNOLOGY NECESSARY FOR DEVELOPMENT OF A LOW COST, HIGH RELIABILITY HOT GAS MANIFOLD.

APPROACH:

- SELECT THE SSME AS A DESIGN POINT:
  - DESIGN COMPONENT IN-HOUSE
    - STRUCTURAL & DYNAMIC ANALYSIS
    - THERMAL ANALYSIS
  - PROCUREMENT - STRUCTURAL CASTING
  - MANUFACTURE AND ASSEMBLY IN-HOUSE
  - TEST AND VERIFICATION IN-HOUSE

SCHEDULE:

• DESIGN AND ANALYSIS	JUNE 91 - JAN 92
• PROCUREMENT OF STRUCTURAL CASTING	JAN 92 - JAN 93
• MANUFACTURE & ASSEMBLY	JAN 93 - JAN 94
• TEST & VERIFICATION	JAN 94 - DEC 94

COST: 4 M

TITLE: ADVANCED GAS GENERATION FOR MULTI-PHASE OPERATION (O_2/H_2 PROPELLANTS)

OBJECTIVE: DEVELOPMENT AND DEMONSTRATION OF A O_2/H_2 GAS GENERATOR WHICH IS STABLE AND HAS HIGH PERFORMANCE UNDER "ANY" OPERATION CONDITION OR PROPELLENT PHASE.

APPROACH:

- USE INJECTOR DESIGN CODES TO SELECT POTENTIAL CANDIDATES
- EVALUATE CANDIDATE ELEMENT CONCEPTS AT THE MSFC COMBUSTION PHYSICS LABORATORY FACILITY (COLD FLOW SCREENING)
- POTENTIAL CANDIDATES WILL BE HOT FIRE TESTED AT TS 116 PREBURNER POSITION.

SCHEDULE:

• CANDIDATE SELECTION	JUNE 91 - JUNE 92
• COLD FLOW SCREENING	JAN 93 - JUNE 93
• HOW FIRE EVALUATION	JAN 94 - JUNE 94

COST: 1M

TITLE: ADVANCED MAIN COMBUSTION CHAMBERS CYCLE LIFE DEMONSTRATIONS

OBJECTIVE: DEMONSTRATE THE CYCLE LIFE CAPABILITY OF PROMISING CONCEPTS FOR ADVANCED CHAMBER DESIGN

- VACUUM PLASMA SPRAYED LINERS
- * PLATELET LINERS
- LIQUID METAL DIFFUSION BONDED LINER (REDUCED MATERIAL PROPERTIES)
- HIGH ASPECT RATIO COOLANT CHANNELS - EDM FORMED
- GRADATED OXIDATION RESISTANT (BLANCHING) METALLIC COATING (VACUUM PLASMA SPRAYED)
- GLIDCOP (MATERIAL) LINER
- POWDER METAL

APPROACH: FABRICATE "40K THRUST" SUBSCALE CHAMBERS AND TEST FOR 100+ THERMAL CYCLES EACH AT TS116 AT MSFC.

SCHEDULE: SIX MONTH TEST SERIES EACH

COST:

* CURRENTLY SCHEDULED

COMBUSTION STABILITY FOR HYBRID ROCKET ENGINES

LIQUID-SOLID HYBRID ROCKET ENGINES MAY BE SUBJECT TO COMBUSTION INSTABILITIES RELATED TO LIQUID OXIDIZER FEED LINES, COMBUSTION PROCESSES, AND FLOW PROCESSES.

DATA ARE REQUIRED ON THE OXIDIZER ATOMIZATION PROCESSES, BURNING RATES, FLOW ENHANCEMENT OF BURNING RATES, EFFECTS OF SUSPENDED DROPLETS AND PARTICLES, VORTEX SHEDDING EFFECTS, AND OTHER COMBUSTION CHAMBER PROCESSES.

COMBUSTION STABILITY MODEL CAN BE DEVELOPED AND VALIDATED USING THE DETAILED PHYSICAL DATA.

COST - ABOUT $200K PER YEAR (2 YEARS)

ADVANCED DIAGNOSTICS FOR COMBUSTION AND FLOW

LASERS AND OTHER OPTICAL EQUIPMENT ARE REQUIRED TO SUPPORT MEASUREMENTS RELATED TO COMBUSTION STABILITY AND COMBUSTION PHYSICS AND CHEMISTRY. THREE DIMENSIONAL PHASE DOPPLER PARTICLE ANALYSIS CAPABILITY IS REQUIRED FOR ATOMIZATION, EVAPORATION, AND DROPLET BURNING STUDIES.

DATA WILL BE USED FOR COMBUSTION AND COMBUSTION STABILITY MODEL VALIDATION, AND FOR DESIGN STUDIES ON PROTOTYPE INJECTOR ELEMENTS.

COST - ABOUT $200K PER YEAR (3 YEARS)

PERFORMANCE ANALYSIS FOR HIGH TEMPERATURE ENGINES

CURRENTLY USED ROCKET ENGINE PERFORMANCE ANALYSIS MODELS REQUIRE UPGRADING TO DEAL WITH HIGH TEMPERATURE WORKING FLUIDS SUCH AS THOSE IN NUCLEAR POWERED ENGINES FOR A MARS MISSION. SPECIFICALLY, UPDATED CHEMISTRY DATA ARE NEEDED.

COST - $100K (1 YEAR)

TITLE: INJECTOR / MAIN COMBUSTION CHAMBER WALL COMPATIBILITY OPTIMIZATION STUDIES

OBJECTIVE: EVALUATE INJECTOR EFFECTS ON CHAMBER WALL COMPATIBILITY TO DESIGN FOR INCREASED CHAMBER LIFE.

APPROACH: BY USING EXISTING "40K" CALORIMETER HARDWARE, EVALUATE THE EFFECT ON WALL HEAT FLUX & RESULTING WALL TEMPERATURE ON THE FOLLOWING

- LOX COAX SWIRL vs. LOX COAX SHEAR ELEMENT
- OUTER ROW ELEMENT SCARFING
- OUTER ROW ELEMENT CANTING (INBOARD)
- FILM COOLING vs. MIXTURE RATIO BIAS
- OUTER ROW WALL GAP

SCHEDULE :

- HARDWARE FABRICATION - ONE YEAR
- TESTING & DATA EVALUATION - ONE YEAR

COST: 1M