

Direct Energy Conversion For Nuclear Propulsion At Low Specific Mass Project

Center Innovation Fund: JSC CIF (Also Includes JSC IRAD) Program

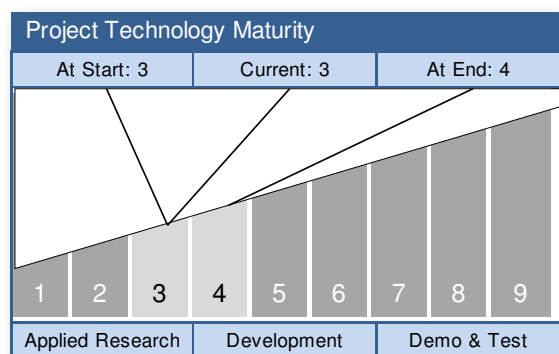
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National Aeronautics and
Space Administration

ABSTRACT

The project will continue the FY13 JSC IR&D (October-2012 to September-2013) effort in Travelling Wave Direct Energy Conversion (TWDEC) in order to demonstrate its potential as the core of a high potential, game-changing, in-space propulsion technology. The TWDEC concept converts particle beam energy into radio frequency (RF) alternating current electrical power, such as can be used to heat the propellant in a plasma thruster. In a more advanced concept (explored in the Phase 1 NIAC project), the TWDEC could also be utilized to condition the particle beam such that it may ...**Read more on the last page.**

TWDEC Test Article at NASA Johnson Space Center



Technology Area: Space Power & Energy Storage TA03 (Primary)
In-Space Propulsion Technologies TA02 (Secondary)

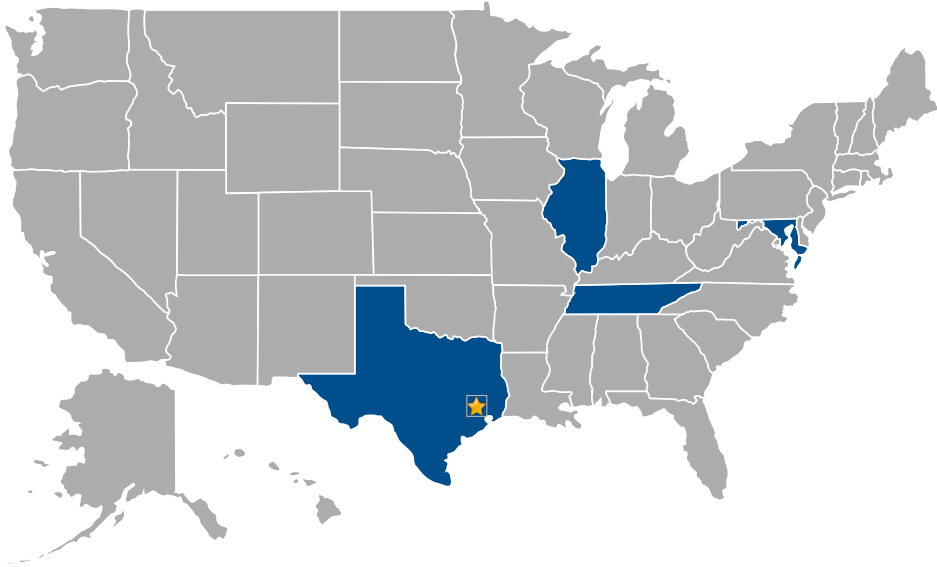
ANTICIPATED BENEFITS

To NASA unfunded & planned missions:

With successful development of this system by NASA and its partners, an intermediate NASA infusion step would demonstrate megawatt-class aneutronic fusion (p-11B fusion), TWDEC, and electric propulsion (e.g., Quantum Vacuum thruster, VASIMR) systems on robotic missions into deep space. Human vehicle system development would then integrate such systems into the "ultimate" NASA application: sustainable, routine human exploration of Mars and, with successful Q-thruster development, ...

Read more on the last page.

■ U.S. states with work



Other Organizations
Performing Work

Electric Power Research
Institute

★ Lead center: Johnson Space Center

Contributing
Partners

U.S. Navy
University of Illinois
Shell USA
(more on last page)

DETAILED DESCRIPTION

Low specific mass ($< 3 \text{ kg/kW}$) in-space electric power and propulsion can drastically alter the paradigm for exploration of the Solar System, changing human Mars exploration from a 3-year epic event to an annual expedition. A specific mass of $\sim 1 \text{ kg/kW}$ can enable 1-year round-trips to Mars, regardless of alignment, with the same launch mass to low Earth orbit (350 mT) estimated by the Mars Architecture 5.0 study for a 3-year conjunction mission. Key to achieving such a propulsion capability is the ability to convert, at high efficiency and with only minimal losses rejected as heat via radiators, the energy of charged particle reaction products originating from an advanced fission or aneutronic fusion source directly into electricity conditioned as required to power an electric thruster. The TWDEC concept accomplishes this by converting particle beam energy into radio frequency (RF) alternating current electrical power, such as can be used ...

MANAGEMENT

Program Executive:
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Program Manager:
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Project Manager:
John Scott
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Co-Investigator:
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DETAILED DESCRIPTION (CONT'D)

to heat the propellant in a plasma thruster.

The project is core to the development of multi-MW power for electric propulsion. The technology developed will enable high power systems which have specific mass in the low single-digits and which are sun-independent, require no neutron shielding, and produce no radioactive waste. The power levels and specific mass this technology could provide will, when combined with either high-efficiency Q-thrusters or VASIMR-class plasma thrusters, enable rapid human missions to Mars and beyond.

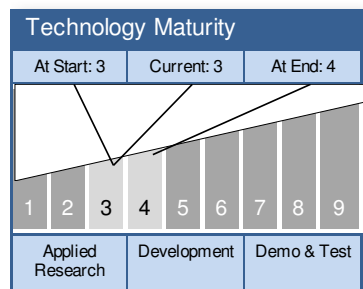
Project Infusion Path:

Low specific mass (~ 1 kg/kWe) in-space electric power and propulsion can drastically alter the paradigm for exploration of the Solar System, changing human Mars exploration from a 3-year epic event to an annual expedition. An ~ 1 kg/kWe can enable 1-year round-trips to Mars, regardless of opportunity, with the same launch mass to low Earth orbit (350 mT) estimated by the Mars Architecture 5.0 study for a 3-year conjunction mission. Key to achieving such a propulsion capability is the ability to convert, at high efficiency and with only minimal losses rejected as heat via radiators, the energy of charged particle reaction products originating from an aneutronic fusion source directly into electricity conditioned as required to power an electric thruster. The TWDEC concept (originally conceived in Japan in the 1990's for terrestrial fusion applications) accomplishes this by converting particle beam energy into radio frequency (RF) alternating current electrical power, such as can be used to heat the propellant in a VASIMR-class plasma thruster. In a more advanced concept (explored in a 2012 Phase 1 NIAC project), the TWDEC could also be utilized to condition the particle beam such that it may transfer directed kinetic energy to a target propellant plasma for the purpose of increasing thrust and optimizing the specific impulse. While other government agencies and/or industry partners are pursuing aneutronic fusion reactors and plasma propulsion, NASA JSC is the only entity advancing this core energy conversion technology (Fig. 3).

With successful development of this system by NASA and its partners, an intermediate NASA infusion step would demonstrate megawatt-class aneutronic fusion, TWDEC, and electric propulsion (e.g., Q-thruster, VASIMR) systems on robotic missions to the Jovian moons. Human vehicle system development would then integrate such systems into the "ultimate" NASA application: sustainable, routine human exploration of Mars and, with successful Q-thruster development, beyond.

TECHNOLOGY DETAILS

Direct Energy Conversion for Nuclear Propulsion at Low Specific Mass



TECHNOLOGY DESCRIPTION

Low specific mass (< 3 kg/kW) in-space electric power and propulsion can drastically alter the paradigm for exploration of the Solar System, changing human Mars exploration from a 3-year epic event to an annual expedition. A specific mass of ~ 1 kg/kW can enable 1-year round-trips to Mars, regardless of alignment, with the same launch mass to low Earth orbit (350 mT) estimated by the Mars Architecture 5.0 study for a 3-year conjunction mission. Key to achieving such a propulsion capability is the ability to convert, at high efficiency and with only minimal losses rejected as heat via radiators, the energy of charged particle reaction products originating from an advanced fission or aneutronic fusion source directly into electricity conditioned as required to power an electric thruster. The TWDEC concept accomplishes this by converting particle beam energy into radio frequency (RF) alternating current electrical power, such as can be used to heat the propellant in a plasma thruster.

This technology is categorized as a hardware subsystem for ground scientific research or analysis

- Technology Area
 - TA03 Space Power & Energy Storage (Primary)
 - TA02 In-Space Propulsion Technologies (Secondary)

Technical Merit: The TWDEC may offer a new paradigm for human exploration of the Solar System through harnessing nuclear fission and aneutronic fusion energy at a power level high enough and specific mass low enough to enable round-trips to Mars of duration under one year. This project will examine key system integration assumptions and rigorously assess the degree to which TWDEC technology at the current state-of-the-art can be optimized for spacecraft power applications.

In FY'14 the following Objectives will be met;

- Activate JSC TWDEC breadboard test article. Conduct validation of TWDEC simulation completed in FY13 to raise TWDEC technology to TRL ...

Performance Metrics		
Metric	Unit	Quantity
in-space power system specific mass	kg/kWe	1 to 3

TECHNOLOGY DETAILS

CAPABILITIES PROVIDED (CONT'D)

4.

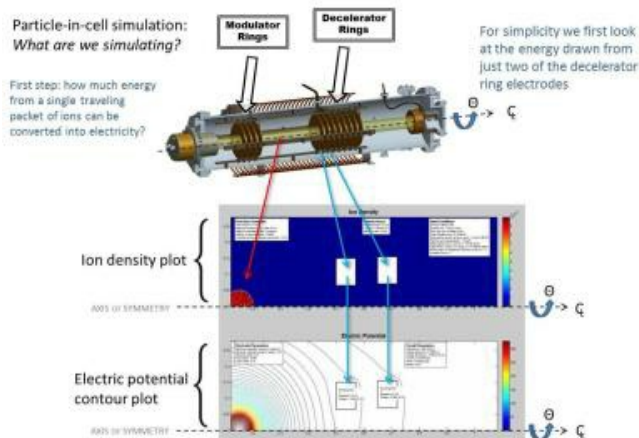
- Build specific mass models, including radiation shielding, of TWDEC-Fusion and TWDEC-Fission power systems for use in trajectory assessments with COPERNICUS analysis tools.
- Assess the impact of the low specific-mass space propulsion enabled by TWDEC on Mars human exploration architectures.

POTENTIAL APPLICATIONS

In-Space Propulsion,

Green Power for Terrestrial energy needs.

IMAGE GALLERY



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NASA JSC TWDEC Test Article 2014

ABSTRACT (CONTINUED FROM PAGE 1)

transfer directed kinetic energy to a target propellant plasma for the purpose of increasing thrust and optimizing the specific impulse.

The overall scope of the FY13 first-year effort was to build on both the 2012 Phase 1 NIAC research and the analysis and test results produced by Japanese researchers over the past twenty years to assess the potential for spacecraft propulsion applications. The primary objective of the FY13 effort was to create particle-in-cell computer simulations of a TWDEC. Other objectives included construction of a breadboard TWDEC test article, preliminary test calibration of the simulations, and construction of first order power system models to feed into mission architecture analyses with COPERNICUS tools. Due to funding cuts resulting from the FY13 sequestration, only the computer simulations and assembly of the breadboard test article were completed. The simulations, however, are of unprecedented flexibility and precision and were presented at the 2013 AIAA Joint Propulsion Conference. Also, the assembled test article will provide an ion current density two orders of magnitude above that available in previous Japanese experiments, thus enabling the first direct measurements of power generation from a TWDEC for FY14. The proposed FY14 effort will use the test article for experimental validation of the computer simulations and thus complete to a greater fidelity the mission analysis products originally conceived for FY13.

The previous FY13 effort focused on computer simulations of TWDEC physics to build engineering tools with which to design vehicle systems around TWDEC power. The FY13 project also supported initial build-up of a bench-top system for experimental validation of the TWDEC simulations developed.



ANTICIPATED BENEFITS

To NASA unfunded & planned missions: (CONT'D)

beyond.

FY'14 Project - Development and implementation of this technology will be in direct support to OCT's Grand Challenge for Access to Space. Future infusion of this technology into human and robotic exploration mission architectures will be identified by the Human Architecture Team and the Mars Program Planning Group (MPPG). This technology will enable a new class of missions for human exploration of the Solar System.

To other government agencies:

Green, high density, energy from this technology would support the missions of the Department of Energy and of the Department of Defense.

To the commercial space industry:

Development of the TWDEC will support efforts by the Department of Energy and Department of Defense to develop aneutronic fusion reactors.

To the nation:

Successful development of the complete power system could enable terrestrial, high capacity factor, electric power generation that produces neither carbon emissions nor nuclear waste. There is of special interest to the utility industry in the private sector .

CONTRIBUTING PARTNERS (CONT'D)

- University of Maryland

