LA-UR-15-27719

Approved for public release; distribution is unlimited.

Title: Reactor Power for Large Displacement Autonomous Underwater Vehicles

Author(s): Mcclure, Patrick Ray
Reid, Robert Stowers
Poston, David Irvin
Dasari, Venkateswara Rao

Intended for: PentaChart for use by Program Offices

Issued: 2016-08-24 (rev.1)

Disclaimer:
Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the Los Alamos National Security, LLC for the National Nuclear Security Administration of the U.S. Department of Energy under contract DE-AC52-06NA25396. By approving this article, the publisher recognizes that the U.S. Government retains nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

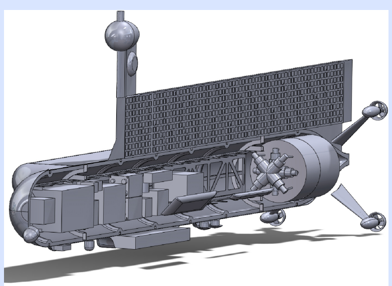
Reactor Power for Large Displacement Autonomous Underwater Vehicles

Nuclear power in a AUV removes any time limitation on a mission, extending it from weeks to years

Background / State of the Art

- Currently AUVs use batteries or combinations of batteries and fuel cells for power
- Battery/fuel cell technology is limited by duration
- Batteries and fuel cells are a good match for some missions, but other missions could benefit greatly by a longer duration

Innovation

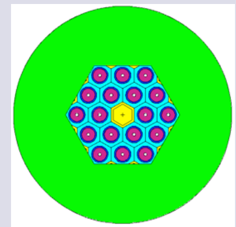


- Adapting space reactor designs for use in an AUV
  - Goal is to adapt several power levels from 1 kWe to 150 kWe
  - Non-proliferation is a must!
  - Fitting the reactor and shielding into the AUV can be challenging

Achievements

MAIN ACHIEVEMENT:

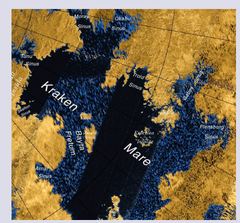
- Multiple designs for AUVs with focus on non-proliferation and packing.
  - Use of moderation in reactor where appropriate to lower amount of U_{235} and limit Security Category to 3 or 4.
  - Use water or methane to lower shielding mass



- Design a version of the reactor for a NASA

HOW IT WORKS:

- Small fission system could be used to explore Saturn's moon Titan
  - Reactor will be small highly reflected fast reactor using current LANL space reactor designs
  - Power conversion will be Stirling Engines from NASA

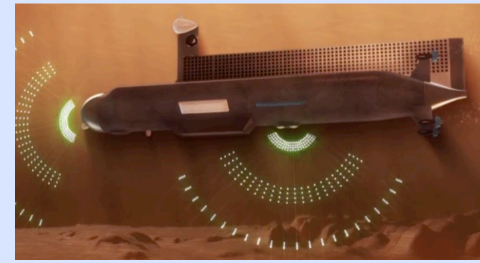


ASSUMPTIONS AND LIMITATIONS:

- Design is limited by the space available
- Design is limited by shielding requirements for electronics

TRL Level 3 – Current designs are conceptual

Impact



- NASA has become very interested in idea of nuclear powered AUVs for exploration
  - Current design would need 32 kg Pu-238 for radioisotope power
  - Reactor can accomplish same mission with 25 kg HEU core

Goals / Action Plan

Goals

- Design nuclear systems to power an AUV and meet design constraints including:
  - Non-proliferation issues
  - Power level
  - Size constraints
  - Power conversion limitations

Action Plan

- Continue development of a range of systems for terrestrial systems
- Focus on a system for Titan Moon as alternative to Pu-238 for NASA

Point of Contact: Patrick McClure, NEN-5, pmcclure@lanl.gov (505) 667-9534

UNCLASSIFIED

Status: Complete

Deliverable	Date	Status	Comments (include date completed)
Reactor Designs	Jun 2015	●	Finished
Shielding Studies	Aug 2015	●	Finished
Packaging & Power Conversion	Sept 2015	●	Finished
Develop into final design	Sept 2015	●	Finished

Issues:

- Potential concern/perception with unmanned nuclear systems

Future Directions:

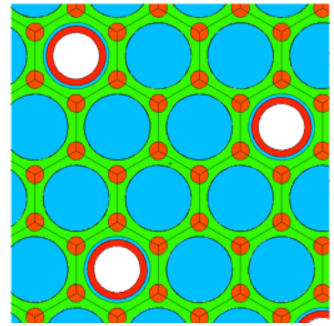
- Pursue program development for Saturn Moon Titan Explore Submarine with NASA
- Pursue program development with DoD and NNSA

Contacts:

- Continued support from NASA
- Interactions with Defense Science Board on military fission systems
- Interactions with NNSA for AUV systems

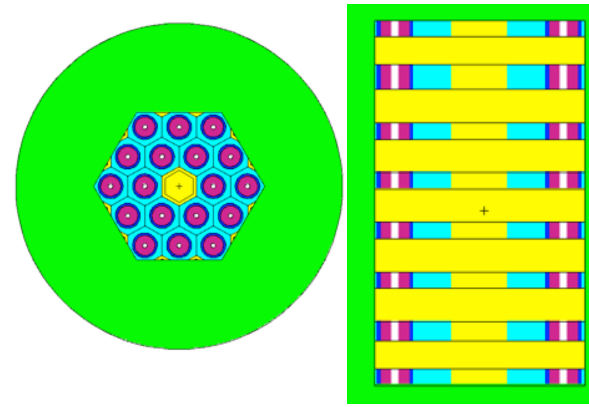
Reactor Concepts

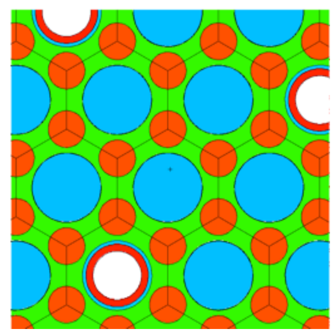
Reactor Description	Thermal Power	Electric Power	Dia.	Length (cm)	Amount of U^{235} in Core (kg)	Core Weight (kg)	Weight plus Shield	Security Category	Peak Temp
Fast Reactor w/ Uranium Oxide Fuel	600	150	86	120	304	3700	5440	4	650
Moderated Reactor w/ Uranium Oxide Fuel and YH Moderator	600	150	85	117	277	3420	5100	4	650
Fast Reactor w/ Uranium Nitride Fuel	500	125	77	101	256	2800	4170	4	650
Moderated Reactor w/ Uranium Nitride Fuel and YH Moderator	500	125	75	99	233	2575	3900	4	650
Fast Reactor w/ Uranium Oxide Fuel	150	38	86	100	263	3100	4500	4	650
Fast Reactor w/ Uranium Nitride Fuel	150	38	77	90	227	2480	3650	4	650
Moderated Reactor w/ Uranium Oxide Fuel and YH Moderator	150	38	76	102	58	2010	3280	4	650
Moderated Reactor w/ Uranium Zirconium Hydride Fuel	175	22	60	80	55	1060	1925	4	500
Fast Reactor w/ Uranium Metal Fuel, HEU	4	1	31	40	30	135	310	1	800
Fast Reactor w/ Uranium Metal Fuel, MEU	4	1	38	42	39	230	420	3	800
Fast Reactor w/ Uranium Metal Fuel, LEU	4	1	52	62	94	880	1100	4	800
Moderated Reactor w/ HEU Uranium Carbide Fuel and YH Pins	4	1	42	46	6	165	350	3	800
Moderated Reactor w/ HEU Uranium Metal Fuel and YH Plates	4	1	31	48	6	107	300	3	800
Moderated Reactor w/ LEU Uranium Oxide Fuel and YH	4	1						4	800



Interstitial Geometry (Small Pin)

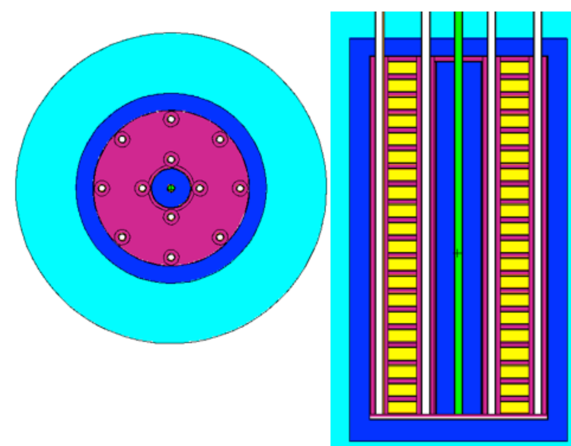
Fuel/Moderator Pin Geometry





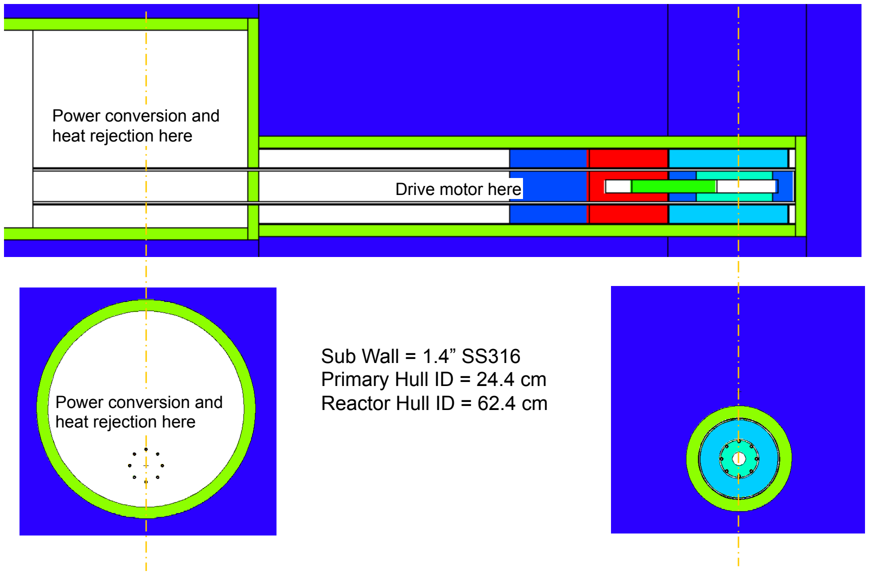
Interstitial Geometry (Large Pin)

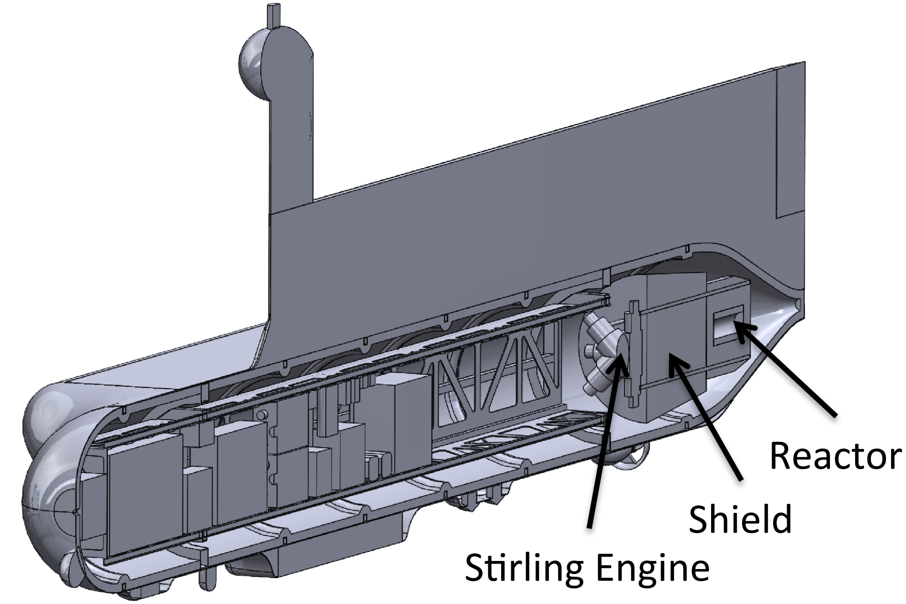
Fuel Plate Geometry



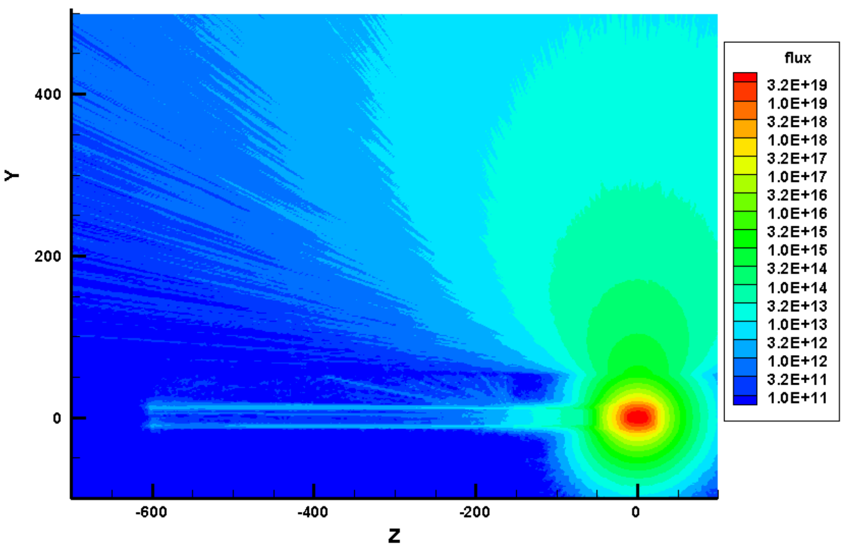
Shielding and Packaging

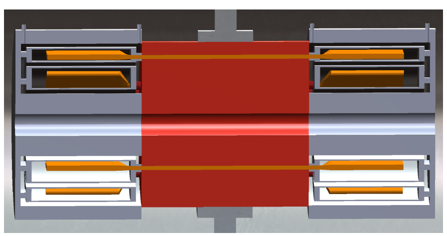
Titan Reactor MCNP Model





Fast neutron fluence: 0 cm below surface
25 cm Be, 25 cm LiH, 2 yr full power operation





Thermal-Photo-Voltaic (TPV) Power Conversion

Reactor & TPV Power Conversion