Noble gas augmented & repurposed habitats, payloads, hybrid in space stages, Noble gas inflated hypersonic decelerators, Cryogenic Neon expansion ratio “battery”

Steven Rappolee; Terrestrial & Cislunar Exploration technologies, A post 9/11 Veteran owned concern

- Habitats, payloads, inflatable hypersonic decelerators inflated or pressurized with Noble gases to augment ion electric propulsion engines. In space stages chemical propellant tanks pressurized with Noble gasses in a novel hybrid SEP/Chemical stage.
- Noble gas augmented habitats allows for preposition greater mass in planetary orbits (Mars) and planetary probes with noble gas inflated hypersonic decelerators augments ion propellants for ice giant probes allowing for enhanced maneuvers in orbit IE plane changes at Uranus from polar to equatorial.
- Cryogenic Neon provides for a possibility of a expansion ratio “battery” for Ice Giant planetary probes, produces electrical power for probe, Triton lander, space telescope. Also coolant for a telescope.
- In the NTR data base there are hybrid Chemical/SEP in space stages study’s going back 25 years. In none of these has there been a study utilizing Noble gasses as both chemical stage pressurizer and SEP propellant. In none of those are cryogenic Noble gasses proposed.
- We propose physics and chemical simulated software studies of noble gas as cryogenic and storable propellant pressurizers and SEP propellant(solubility problems). Interesting that recent Titan atmospheric and geological evolution studies also study noble gas and hydrocarbon solubility in Methane, we can contribute to this data base.

NASA and the National Bureau of standards have over 50 years funded software simulation models to model the physics of noble gases, their Binary’s at triple points, solubility, vapor-liquid phase equilibria. These could find a sweet spot Noble gas Binary to act both as chemical tank pressurizer and SEP propellant.

In a NIAC-phase 1 study where a sweet spot fails to close then Neon or Neon Helium binary’s could be mixed with Xenon from a docked habitat and a SEP stage hybrid and habitat payload stack. Xenon and Argon in themselves are most likely poor choices as pressurizers in chemical tanks but they could be mixed with Neon/Helium Binary’s and shunted to a Xenon engine fed by the habitat/space probe.

ISP and weights of the stack can then be notionally modeled to look for trajectories and mass delivered to destinations. We believe the Hybrid stage and the Noble gas augmented habitat might have to work as one system.
**Xenon gas Pressurized habitat’s as SEP stage augmented propellant tanks for prepositioning and radiation shielding**

We propose to pressurize existing and proposed habitats of all sizes to include Skylab-II, Cislunar habitats, cycler habitats, Inflatables (Bigelow) The ISS and Planetary orbital habitats with Xenon or other Binaries of Noble gasses to augment the propellant mass of SEP stages. Habitats could also house Xenon gas under greater pressure in Propellant tanks that also serve as radiation protection. An example would be the ISS, in 2028 you could de-crew the ISS and the interior volume of the ISS would take 7 tons of Xenon to replace air. An AARM derived SEP tug with 11 tons of Xenon would dock with ISS to bring the ISS to a salvage/storage orbit (Herman). Additionally the ISS could be outfitted with Xenon tanks in one or more of its segments. The SLS derived Skylab-II would have an 8.4-meter diameter and the ARRM Xenon tank is 60 centimeters in diameter so we could have 14 of these around the inner circumference of the Skylab-II. 14 times X 1,300 Kg of Xenon = 18,200 Kg of xenon! The ARRM Xenon tanks at 305 centimeters with two rows (28 tanks) would take up to 610 CM of Xenon tanks. Skylab-II at 11.15 meters could handle two rows of tanks or 36,400 Kg of Xenon (Herman). The ARRM derived tug has its 10,000 Kg of Xenon so this totals out to 46,400 Kg. Habitats and SEP stages. Planetary probes could also inflate with Xenon Hypersonic atmospheric decelerators (NIAD) to enable orbit insertion “Xe-NIAD”.

**Skylab-II “MAX”**

SLS LH2 Tank is 130 feet in length & 8.3 meters’ diameter made with 5 barrels so 30 feet per barrel so we propose a much larger Skylab-II placed into LEO. This vehicle could have 72,800 Kg of Xenon in 56 tanks. LEO to Cislunar space and beyond would be the job of a AARM derived vehicle with its augmented payload of Xenon. The SLS first stage is 212 feet high so lofting an empty LH2 tank as a space station would give us a launch vehicle 342 feet high. The LH2 tank is 2,032 cubic meters. This study states that 40 feet of a traditional metal tank weighs 6,764 Lbs. (Ivanco) So by extrapolation The SLS LH2 tank at 130 feet should be at 130/40 = 3.25 & 3.25 X 6,764 Lbs. yields 21,984 lbs. or just short of 10 Mt(?). Extrapolate Xenon Propellant tanks inside this vehicle. These habitats are also possibly Noble gas depots.

Trades and mission design & trajectory’s of SEP propellant augmented habitats

Proposed to be done by NASA Glenn COMPASS team, we assume one of the ARRM derived spacecraft docked to the SEP propellants augmented habituates. Needs study of SEP transfer lines and connections. A SLS LH2 tank in LEO at 40 Mt and 30 Mt Xenon onboard enables Skylab-II MAX when a AARM derived SEP docks with it with its 10 Mt Xenon. ISS delivered to a grave yard/salvage at LDRO orbit takes 20 Mt Xenon installed onboard ISS and a AARM docked with it. A de crewed and de gassed ISS can hold 8 Mt of Xenon in its modules at 1 ATM. Methods for proposed NIAC Phase 1 Hybrid SEP Chemical in space stage and an in space Liquefaction/Fractionation Unit; This unit separates gases O2, H2, Xe and Ne from one another for shunting to ULA’s proposed IVF engine and the SEP engine in our proposed hybrid stage.

We can use numerical modeling software designed to model chemical and physics of Noble gases and their Binaries in reaction to their proposed use as pressurizers with cryogenic and storable propellants and oxidizers. Surprisingly very little work has been done here in the last 60 years in regards to anything other than helium as the tank pressurizer. Much work has been done on Noble gases and their Binaries as interesting objects of low temperature physics and as enablers of astronomical and physics experiments. Wang & Sadus report cryogenic Helium as well as Neon show quantum affects at their vapor fluid interface.
(Wang) Wang & Sadus researched Binaries of Argon and Krypton\(^1\). We propose to Niac Phase 1 that the work of Hibbard from 1968 is compelling in the use of Neon with LCH4 (Hibbard). We propose to Niac that we repurpose and reuse Noble gasses as pressurizers and propellant’s and as such we would not want a noble gas that has high rates of miscibility in the oxidizer or propellant\(^2\) yet at the same time we look for a good candidate as an ion propellant. We also propose to study the physics of the other Noble gasses in contact with Cryogenic and storable propellants and oxidizers. Do they form ice? Most likely. Neon is a good choice(?) but it’s not the ideal SEP propellant. We propose to NIAC phase 1 that physics and chemistry modeling programs be used to model Noble Gas Binaries to look for sweet spots for duel use noble gas pressurerent/SEP propellants. Would a Neon Argon Binary be a better candidate? 
(Nasrabad)\(^3\) How would Noble gas and Binary’s behave when pressurizing LH2 Gels? (Palaszewski) We believe a cryogenic Methane Hydrogen gel might behave well with a Neon or neon Binary propellant tank pressurizer, Vander Wall elaborates on Methane and other Hydrocarbons as colloids in LH2 (Vander Wall) The in space Liquefaction/Fractionation Unit is used to separate gases H2,O2,Xe from one another in the chemical stage tanks. We propose a hybrid Xues lander that uses it for ISRU.

**Xenon Neon binaries as dual use pressurants & SEP propellants**

A Neon Nitrogen Binary for example lowers the triple point of Nitrogen so it can be of better use in accelerators (de Sousa) In NiAC phase 1 we should look for Binaries with Xenon the SEP propellant of choice and Neon and Helium the cryogenic propellant pressurizer of choice\(^4\). We propose NASA Glenn COMPASS team to use the software programs that model noble gas and binaries triple points and propellant oxidizer interface ****Trades with use of Neon only in hybrid stage and transfer of Neon to be mixed with Xenon from the AARM derived stage & augmented habitat. Here we come full circle, both architectures are meant to work together in whole or in part which is yet another trade space (Cha) This trade would elevate the need for an ideal binary for the chemical stage. Again the fallback study is shunting hybrid stage noble gas to a Xenon engine and then mixing the Propellants. This would result in a Neon/Xenon Binary SEP propellant.

**SEP propellant dual use with inflatable supersonic inflatable decelerators and the proposed Cryogenic Neon Battery (and Iodine option)**

Deep space probes and habitats alike could benefit from inflatable atmospheric decelerators(HIAD), what are the trades to duel use of SEP propellants to perform the mission of inflation? A habitat could go into an equatorial orbit about Mars saving propellants with a decelerator and run the SEP engines of Xenon in the spent inflatable into a polar orbit or some other destination. The Uranus probe could use this SEP

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\(^1\) Gibbs-Duhem Monte Carlo simulations are reported for the vapor-liquid phase coexistence of binary argon + krypton mixtures at different temperatures (Wang & Sadus)
\(^2\) Therefore, it appears that only neon, hydrogen, and helium can be used as pressurants if liquefied natural gas is to be used in aircraft unless the gases and liquid fuel are separated by a barrier. (Hibbard)
\(^3\) Gibbs ensemble Monte Carlo simulations were used to test the ability of intermolecular pair potentials derived ab initio from quantum mechanical principles, enhanced by Axilrod-Teller triple-dipole interactions, to predict the vapor-liquid phase equilibria of pure neon, pure argon, and the binary mixtures neon-argon and argon-krypton (Naserabad et al)
\(^4\) Theoretical studies show that neon can influence the phase diagram of nitrogen, lowering its triple-point temperature (Sousa et al)
propellant to maneuver from a polar Juno type orbit into a Moons plane mission as has been suggested for the next Mars orbiter mission (Zurek). We Propose a NIAC study of a AARM derived Uranus or Neptune probe with additional Xenon to inflate the decelerator. This duel use may be the happy sweet spot in the case of Uranus who’s Moons orbital plane requires the ISP. All study’s point to a decelerator at Neptune as well so NIAC Phase-1 would do trades on the non-inflatable decelerators and the inflatable ones with the caveat that we use Xenon to inflate. Many (HIADs) studies could be repurposed to the use of Noble gas as pressurizer and to model volume and ISP of the gas (Lyle) (Del Corso) (Bodkin) (Johnson) (Swanson) (Majumdar) in this Niac Phase -1 proposal, Trade space with these EDL ideas (Venkatapathy). We propose to model in NIAC phase -1 Xenon inflated NIAD for our proposed Xenon pressurized Habitats for planetary orbit insertion and subsequent SEP maneuvering (Xe-NIAD).

Ground-based facilities keep cryogenic battery cold, LH2 boil-off keeps cold, expansion to gas of Neon generates electricity to spacecraft or lander at destination. One Proposal draws on NASA Glenn long term storage of LH2/LO2 for planetary missions (Mustafi).Iodine solids in a colloid mixed with Cryogenic Neon provides an opportunity to share tank mass with two propellants. This calls for the need to model Neon/Iodine Xenon binary’s/Colloids as propellant (Polzin).

(A) SEP propellant dual purposed as chemical stage tank pressurizer. (B)SEP propellant dual purposed as habitat inflated or habitat pressurizer (SEP propellant augmentation) or use of Tanks in habitat (C) SEP propellant dual purposed as space probe, habitat, inflatable hypersonic decelerator inflator gas(D) Cryogenic Neon as a battery utilizing the Neon expansion ratio to generate electricity: Neon to SEP engine (E) Possibly Neon Battery expansion ratio provides modest thrust to EDL to a Triton or Titan lander (cold gas thruster)

NIAC Phase -1 experiment protocol

Noble gases as a pressurizer for oxidizers and propellants can be experimentally simulated (Tchouar)6 So we believe the simulation of Cryogenic Neon under pressure evaporating to gas and driving a turbine for electrical generation is possible to model by NASA Glenn Compass team. Mass, ISP and trajectory trades for Noble gas augmented & repurposed habitats, payloads, hybrid in space stages, Noble gas inflated hypersonic decelerators. These can be compared to existing COMPASS mission designs for planetary missions as well as existing study’s for HEFT that examine human crewed and human tended habitats at Cislunar and Mars orbit. We believe our novel concepts will trade well with existing ideas, the habitat augmented with Xenon pressurized tanks is deceptively simple it should be modeled. The Binary Noble chemical tank pressurizer SEP dual use and the Xenon inflated NIAD planetary probe and Cryogenic Neon Battery electrical generator are deceptively complex, are they really? NIAC-phase-1 is the ideal platform to carry out this enquiry.

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6 The prediction of thermodynamic properties of liquids and mixtures is still an issue of interest in simulation. The literature shows that these systems are widely investigated in both experimental and theoretical ways [1,2,3,4,5]. X-rays scattering of liquid methane near the triple point (90.7 K°) [6,7,8,9,10], and liquid nitrogen [11] were studied. Theoretically new simulations with path-integral formalism have been conducted to obtain thermodynamic


