Title: ILNSS : Network for position on Lunar surface and interplanetary prototype
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(√) We apply for student Prize.
(√) Please keep our idea confidential if we are not selected as finalist/semi-finalist.

Mission Objectives (where and why?)

The first phase of space colonization, It is not yet possible to determine the geographic coordinates of the planet surface effectively. Especially, In landing an auxiliary spaceship or a large spaceship. If there was a colony already in place, this may cause damage to the colonies or existing assets on the surface. And also specifying the position, can also help in navigating to various destinations. In addition, to explore the lunar or interplanetary surface without using a lot of calculations and can also be controlled by a space gateway or DSN Earth ground station. So our mission objectives are..

1. To create a temporary position and navigation networks using in space as standardized to being a prototype for space colonization.
2. To assist the space mission in exploring, managing, and landing spacecraft with less risk than the Range Trigger method.
3. To be a prototype for colonizing position and navigation networks.
4. To use the results from experiments to develop and improve navigation and positioning on uncertain interplanetary planet terrains.

Concept of Operations including orbital design

It is a reference to a location and geographic coordinates. PETASUS, the ILNSS satellite, works similarly to the GNSS network on the earth that relies on multiple satellites to determine the coordinates of the object which to be located. It needs a stable orbit for long term usage, so we chose a distant retrograde orbit (DRO) because of the stability of the orbit, also distance from the orbit and the surface enough to keep track of colonized aviation and the orbit is elliptical orbit which make it easily to calculate and control the spacecraft incoming from every side of planet.

The deployment of PETASUS needs a dispenser to deploy multiple satellites into different geolocations of the planet so we need to put PETASUS as payloads to PETASUS-D, the dispenser spacecraft, with the optimal velocity of each phase, escaping the gravity to LEO (1,000 km) we need 28.234 km/s for each dispenser with 16 payloads, for transfer the orbit from LEO to DRO at 61,500 km altitude from the moon surface we need about 19.420 km/s for 324,304.260 of t_H which equal to 3.753 days then use ion thrusters to control the velocity to 28.238 m/s which is synced to lunar surface velocity. For network operation, due to the interoperability of satellites, this will make the geolocation able to be specified in the spherical position Makes it possible to specify both position and height. The height axis is less accurate than the surface axis. This creates a by-product of knowing the size and shape of the moon in 3D models that can be studied and planned to build a city plan on the moon in the future.

All of the operations of PETASUS are preferred to be an auxiliary mission of spacecraft landing; We can reuse our satellites until the ray decay is higher than limit. We can divide the PETASUS mission into multiple phases, as shown below.

Preparation Phase

We set up the target position in space to be a static position of satellite orbits by using a mother satellite which goes around the orbit when they reach the optimal point, detaching the PETASUS network satellites payload and waiting for spacecraft incoming. We represent the orders of operation as below.

1. PETASUS-D (PETASUS Dispenser) detaches from the envelope.
2. PETASUS-D uses a propulsion system to align into the orbit and correct direction to dispense (facing or perpendicular to the planet surface).
3. PETASUS-D initiated communication to DSN to confirm its position in space; PETASUS-D started dispensing the first PETASUS to orbit.
4. PETASUS uses a propulsion system to align into the target orbit.
5. PETASUS-D wait planet orbit passed ϕ_n radian then deployed another PETASUS to the orbit.
6. PETASUS repeat self aligning operations like 4 until all PETASUS set their position.
7. PETASUS recheck the entire orbit to find the optimal position itself if some of PETASUS detached failure by verifying using PETASUS-D and DSN ground station.

ϕ_n represented the optimal radian of orbit to make n^{th}PETASUS uses propulsion fuel appropriately in case of re-orbit by system failures.

Operative phase

We separated this phase into 2 conditions, “Auratos” and “Gnostos”. “Auratos” condition (unseen in Greek) is meant to unseen terrain we doesn’t landed the spacecraft before or the PETASUS don’t have any WAAS or GNSS to determine and reference for error rate of orbit position (In this case, we should deploy the PETASUS satellites little few days before spacecraft arriving to get less error after computed by DSN network). “Gnostos” belong to seen terrain and ground stations installed on the surface which are used for calculating the error of satellite orbit to improve accuracy rather than use DSN to compute the error of networks due to long range data transmission loss and PETASUS will get less accuracy if computed error by using outside sphere network.

For “Auratos” conditions, The satellites start broadcasting radio frequencies to the surface then spacecraft can collect the data received from each satellite node. The position of satellites must be used up to 4 PETASUS satellites because each data from one satellite puts we in a sphere around the satellite. By computing the intersections you can narrow the possibilities to a single point. Three satellites intersection places us on two possible points. The last satellite gives you the exact location. If possible, the spacecraft must contain the ground station services to attach on the surface for PETASUS satellite long term use; this will reduce many positioning errors of PETASUS in uncertainty of orbit movement.

For “Gnostos” condition, according to the installed ground stations, we can do all the same things as Auratos but calculate the error from the ground stations rather than DSN from the earth to improve the accuracy.

By determine the position of spacecraft which PETASUS networks are locator, ours data would broadcast as radio frequency in L-Band and let the receiver receive multiple sets of data transmitted from multiple PETASUS satellites ours data would contain time of establishment signal, epoch time in UNIX format for computation, and the best exact location of satellite after error calculated. For positioning PETASUS as said before, we have 2 methods to determine ours own location, the first is using DSN from the earth ground station to calculating the exact position of our single satellite as shown as picture below

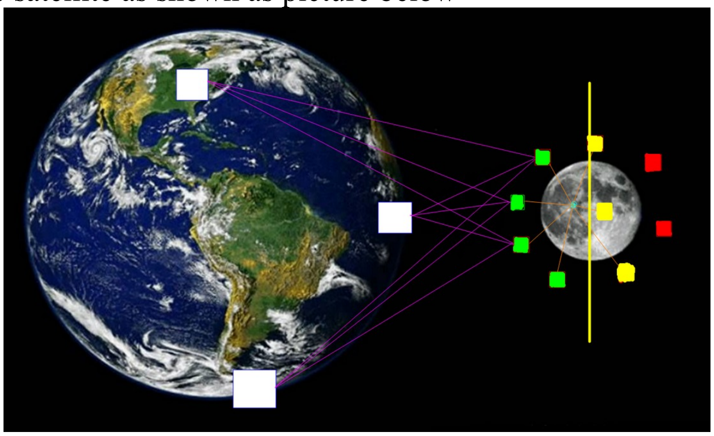

Figure 1. Red boxes represent the satellites in the network which are inactive to reduce power usage on the night side of the moon. Green boxes represent the satellites fully active and will connect to DSN on the earth ground station in time which will change after the satellite changes to another one. Yellow boxes are warming satellites which are going to change state from inactive to active which will be partially operational in operation.

Postoperative phase

After the main operation ended, PETASUS can still orbit around the celestial object and still provide the service. In other plans, we would attach some more gadgets to make the PETASUS being SGIS (Space geographic information system) using Synthetic Aperture Radar (SAR) attached with PETASUS in a single one network, after spacecraft landing operations ended.

How to determine the location of our satellites

If our network is too far from the DSN and our mission will be used on a planet which already has more than 4 orbiters, we might use already existing orbiters which are bigger and have better connection to DSN to calculate our PETASUS position based on the concept 'Nested positioning network'. But for more accuracy we have to include time dilation because of time measure in space compared to the Earth is not the same, from General Relativity state that time at outside of gravitational field is faster than inside of gravitational field but in Special Relative state time measure in inertia frame must be slower relative to non-moving, so if we state that PETASUS is an inertia frame time on DSN must be tick slower for us so if we want to know how our clock in space is run faster than the earth we need to calculate both of them so we get.

$$\Delta t = \sqrt{\left(1 - \frac{2GM_e}{\left(r_e - r\cos\theta\right)c^2}\right)} - \sqrt{1 - \frac{2GM_e}{rc^2}} - \sqrt{\frac{c^2}{c^2 - v^2}}$$

This is how time must run faster in space in 1 second.

How to determine the location of spacecrafts

After known PETASUS networks coordinates, PETASUS will broadcast signals in L-Band to the surface of the planet, with multiple PETASUS we can get multiple intersection of broadcasted signal from vary PETASUS id, so the PETASUS receiver can detect multiple signal information of PETASUS position which can also calculated to itself, ILNSS receiver, positions.

This technique is the same as a GNSS receiver does on the Earth.

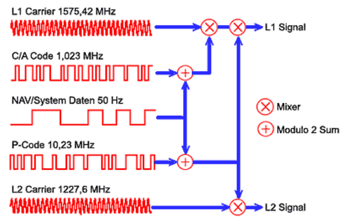

Figure 5. *How ILNSS receiver processes signal received in L-Band before calculating the position.*

Key Performance Parameters

Target Experiment	Minimum expectation	Mission expectation
PETASUS-D reach the orbit with correct direction before dispense PETASUS satellite	Less than 0.79 radian direction error	Less than 0.09 radian direction error
PETASUS-D dispense PETASUS successfully	8	All of PETASUSs
DSN verify when PETASUS reach itself orbit	<5% error rate before calibration	<1% error rate before calibration
Each PETASUS operation time	8 hours	16 hours
PETASUS can locate client in 3D with error*	<50 meters	<15 meters
PETASUS navigate spacecraft landed position error	20-35 meters	< 10 meters
PETASUS synchronously used for positioning	3 PETASUS	> 3 PETASUS
PETASUS life time	2.5 years	4 years or more than
PETASUS Radiation hardening (Max dose)	30 kRad	40kRad
SAR information can downlink to the DSN	reported every 3 days	reported everyday

We considered only the main mission of PETASUS, navigating the spacecraft. For colonization usage, if a spacecraft landed successfully, it means our operation is successfully done because of the same purpose of positioning and navigating.

Space Segment Description

Capacity	Description
Dimension	PETASUS : 10.4 x 10.4 x 32.9 cm Dispenser : 49.2 x 26.2 x 38.6 cm
Weight	PETASUS : 2.993 kg (With SAR and SAP) Dispenser : 22.345 kg (Without payloads)
Communication band	PETASUS : X-Band [XTRP + 2 XLGA] Dispenser : X-Band [XTRP + 2 XLGA] Link budget -116.76 dBm
PETASUS Operation Band	L1 Band (1575.42 MHz)

	L5 Band (1176.45 MHz)
Power	<u>PETASUS</u> : BAT : 2x GOMspace NanoPower BP4 SAP : 13x GOMspace P110 Solar Panel Max Consumption : ~112.4 W <u>Dispenser</u> : BAT : 3x GOMspace NanoPower BPX SAP : 24x GOMspace P110 Solar Panel Max Consumption : ~217.4 W
Propulsion system	<u>PETASUS</u> : 4x MiXi Ion Thruster (Xeon) <u>Dispenser</u> : 4x VACCO's Integrated Propulsion System
Computation units	ISIS On Board Computer (400 MHz)

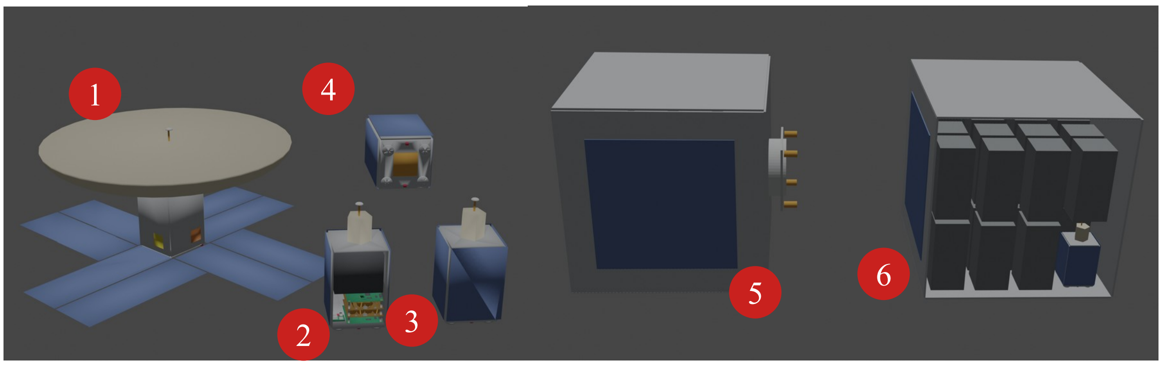

Figure 2. and 3. *Component of PETASUS and PETASUS-D (1) PETASUS after SAR and SAP spanned (2) Represent component inside PETASUS (3) Outside view of PETASUS during deployment process (4) Dispenser module with PETASUS inside (5) PETASUS-D, the dispenser satellite, outside view (6) Represent dispenser module placement inside PETASUS-D*

Additional considerations

PETASUS-D can be a reusable dispenser module by adding more propulsion enough to using Hohmann Transfer orbit back to LEO orbit and sent more payloads for another planet missions or send more PETASUS to the exist systems in the future, this make our missions repeatable and reduce cost of building new dispenser spacecraft for each mission.

References

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