Title: MicroSatellite Miner (MICROMIN)

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(**x**) **We apply for Student Prize.**

(**x**) **Please keep our idea confidential if we are not selected as finalist/semi-finalist.**

Need

To live in space, to send colonies to explore the space, and to maintain space vehicle with its subsystems', the main requirement is energy. For economic purposes the efficient way is to produce the energy/equipment needed at space instead of sending them from Earth. Compared to the cost of having the resources in space rather than transporting from earth is much more feasible and cost efficient. "What's scarce on Earth is plentiful in space, and if you can get your hands on what's out there, you could add trillions of dollars to the global economy" (Cameron, 2012).

Current worldwide efforts :

* Deep Space Industries plans to launch three small crafts armed with cameras, called Fireflies, on an asteroid discovery mission as early as 2015. Three more spacecrafts, called Dragonflies, are expected to launch in 2016 to collect samples to be evaluated for mining potential. [1]

* Planetary Resources, a Seattle company that launched its asteroid-mining operation last year, is developing a space telescope for spaceflight [1].

* The Near Earth Space Surveillance (NESS) mission plans to use NEOSSat to search for and track near-Earth asteroids interior to Earth's orbit around the Sun, including asteroids in the Aten and Atira classes [2].

Mission Objectives

- Exploring the possibility of using microsatellites for meteorite detection and investigation
- Using of infrared sensor to detect composition of meteorites
- Exploring capacity of electric propulsion for nano/microsatellites
- Launching and operating microsatellites to high earth orbits
- Inter satellite communications with nano/micro satellites

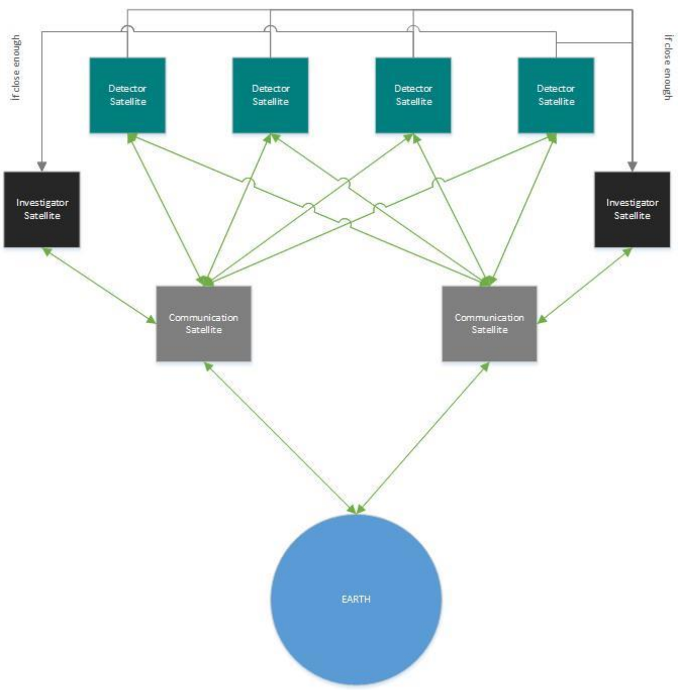
Concept of Operations

Due to limited size and power of nano/micro class satellites, there will three groups of satellite to accomplish the complete mission of finding meteorites (Ms) and examining them, then transferring findings to the earth. Altogether 8 satellites will be developed:

4 detector satellites (DS): these will be located on equally spaced true anomalies on a highly elliptic earth orbit, with a perigee of 20km, and an apogee 80 km, to monitor and detect possible Ms travelling around the earth. Current observations points out that there are about 5 asteroids of suitable size approaching earth between 20km and 80 km, every year (wikipedia).

2 investigator satellite (IS): When detector satellites detects Ms, they will inform IS of the Ms coordinates. Then based on a travel plan IS will use their electric propulsion systems to approach Ms and then following

a suitable closeness they will use their sensors to examine the Ms. They will inform Comms of the results.
2 earth communication satellite (Comms): They will communicate with earth to transfer all the findings. The relationship between satellites is shown below:



There are many available launch system, however just a few of them can inject the spacecraft to GEO orbit with using any onboard propellants; Soyuz and Proton M seems to be the most suitable ones to carry out this mission. Due to small mass of microsattelites/probes Soyuz seems more cost efficient with lower launch cost. The Soyuz launch vehicle can inject a payload directly into Geo-Synchronous equatorial Orbit (GSO) by means of a three-burn Fregat mission. The injection scheme is the same as the one presented for the GTO mission, but with a final Fregat burn to change the inclination and circularize on the GSO.
The maximum Launch Vehicle performance in GSO is 1390 kg.

Key Performance Parameters

Followings need to be determined to assess the mission:

- ADCS angular requirement for Sensor alignment accuracy
- Inter-satellite link requirements
- Infrared sensor resolution requirements
- Required Thrust and Propellant

Infrared sensor Requirements

Infrared sensor needs to be precise for this mission. Having detected a meteoroid M of a suitable size, their material specifications need to be analyzed. The sensor will send multiple beams and then collect the reflected ones in order to understand the material of M's.

Required Thrust and Propellant

Name	thrust	Mass	Diameter	Isp	Power

MiXI	**0.01-1.65 mN**	**0.2 kg**	**3 cm**	**2500- 3000**	**20-50 w**

Engine average specific impulse can be determined from above table, minimum value of Isp is taken into consideration Isp=2500 s; hence exit velocity is determined as follows, V_e=2.4525 $x10^4 \frac{m}{s}$

Next step is to calculate thrust using input power and power efficiency (with 50 watt power input and 40% thrust efficiency):

$$T = \frac{2\, p_t\, \eta_t}{V_e} = 1.6309\, mN$$

Now that thrust is found for a single engine, propellant mass flow for 3 MiXI engines is, $\dot{m}_p$=1.9571x10^-6 kg/s.For a single trip from GEO orbit to 80000 km, required would be, ΔV=9.9111313x10^2 m/s.

Using Tsiolkovsky equation propellant mass for single trip will be, in which wet mass is considered to be 40 kg. As a result propellant mass for a single trip is m_p=1.5842668 kg.

Burn time for a single trip to 80000 km is, t_burn=9.3691795.

Let's say during 4 years mission the approach and investigator micro probes have to travel this path(departing from park orbit, GEO to detected orbit at 80000 km) for 10 times, then propellant mass for 4 years mission duration would be, m_ptot=15.842668 kg.

Space Segment Description

<u>Satellite types</u>: 2 Sats to communicate with Earth ground station, 4 sats to detect Ms, 2 sats to approach and investigate composition of M

Each one with max mass of 50kg, max dimensions of 20*20*40cm for a single or dual launch to GTO.

<u>On board equipment:</u>

- Infrared-light detector (modified smaller NEOcam, to fit in a 20*20*40cm sat.)
- The Near Earth Object Camera (NEOCam) sensor is a new infrared-light detector to improve the performance and efficiency of the next generation of space-based asteroid-hunting telescopes.

We can learn more about asteroids when we look at them with infrared light, when you observe a space rock with infrared, you are seeing its thermal emissions, which can better define the asteroid's size as well as tell you something about composition.

Asteroids emit most of their radiation at infrared wavelengths near about 10 microns (0.0004 inches), which humans perceive as heat. There is also relatively less radiation from stars and galaxies at these wavelengths, which simplifies detection of faint moving objects.

This sensor works at higher temperatures than any other similar ones we have at the moment, this means they can be passively cooled; making the instrument less heavy and less expensive to put into space.

The NEOCam sensor is made of mercury, cadmium, and tellurium. Pipher and her colleague Forrest started working on sensors from this combination of materials nearly 20 years ago, when they saw the potential they offered for higher operating temperatures

- Electric propulsion system (MIXI, 17 W)

The 3 cm miniature Xenon ion thruster is a low- noise, low-contamination thruster that is currently being developed in JPL. This thruster is ideally suited for continuous, low-disturbance, solar torque compensation missions, precision repeat path or orbit control missions and most importantly precision formation flying missions. Its properties are:

- For main delta-v propulsion of 30-100 kg spacecraft if power > 20 W is used.
- Well-suited for near-Earth/lunar/interplanetary missions where high delta-v is needed due to relatively high specific impulse (3000 s).
- Low thrust requires long mission trip times -spiral trajectories.
- Special applications include formation flying of a constellation of spacecraft, or drag make-up in low Earth orbits.

- Intersatellite links or crosslinks provide direct connectivity between two or more satellites, thus eliminating the need for intermediate ground stations when sending and receiving data.

Intersatellite data flows from detection satellites to communication satellites and investigator satellites, then from communication satellites to the earth. L Band frequencies (IEEE/ 1-2 GHz) will be used.

- The satellite will have deployable solar panels. Since the propulsion system will work continuously for 9 days, the system batteries will not be enough.

Size of the Ms and range of the sensor may differ. With respect to these values angular stability is important. In order to match accuracy of the angular stability while using sensors 3 axis altitude determination and control system is required.

Mission time of at least 4 years is required for proper M detection and investigation. All satellites shall be as much similar as possible o reduce cost, shall have intersatellite communications and shall have 3 axis ADCS.

Orbit/Constellation Description

Satellite constellation will be consisted of 8 satellites. Two satellites will be on GSO (Geosynchronous orbit) and responsible for main communication system between other satellites and ground station. Four satellites will be located on equally spaced true anomalies on a highly elliptic earth orbit, with a perigee of 20km, and an apogee 80 km.

Whilst Meteorite orbital path is not known as asteroids are, this makes meteorites more difficult target. However, the fact that, some of meteoroids move toward inner solar system and more specifically the Earth; allow us to hunt them with less budget and complexity. In case of Asteroids orbital path is known, so the spacecraft should undergo through a transfer orbit from the earth to reach at desired destination. Executing such mission can be done with quite high reliability since such mission (sending probes to Asteroid belt) is already been carried out by several space agencies like NASA and JAXA (Hayabusa Mission).

Implementation Plan

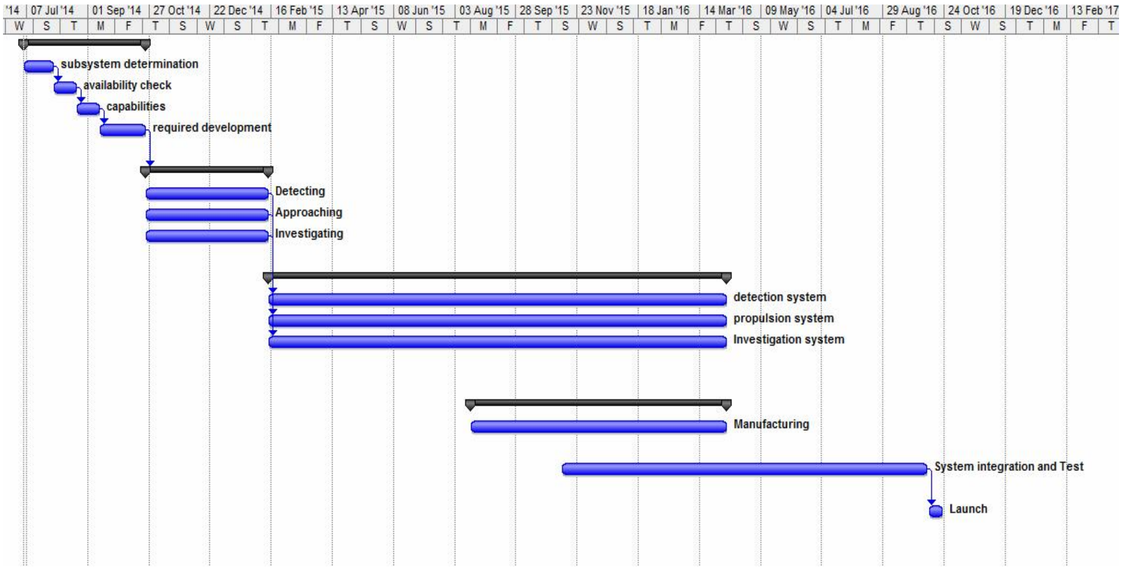
Phase 1: Concept demonstration, launch 3 Sats, test detectors, propulsion systems, approach testing, sensor testing.

Phase 2: System review based on precursor flight, improve systems, and launch actual systems of 8 sats.

Possible players: Governments, space research labs and related private firms (international collaborations with detector developers, mini propulsion system developers, satellite equipment developers), project team, launch providers

<u>Time plan (Phase 1 only)</u>

- Project planning, 4 months, determining subsystems to achieve the goals, assessing what is available, capabilities, needed improvements, selection of systems
- Orbit determination, Detailed Design and procurement of systems, 1-2 year
- System integration and test, 1 year



<u>Budget (Phase 1 only):</u>

- Engineering 3 years, 20 member, $1.5 million
- Equipment procurement, $2 million
- Development (manufacturing, testing, enhancements) $2 million (as much as possible, all test are in Turkey, at ITU Space Labs , Turkish Aerospace Industries Space Test Center and TUBITAK Space Research Center)
- Launch costs $2 million
- Total $7.5 million

<u>Possible Risks</u>

- Some technologies may prove unsuccessful, not ready to use
- Sensor size may be too large
- May cost more than expected
- May take much longer to realize
- Difficulty of Approaching a Meteorite
- Achieving a successful formation flying

If selected for finals, the full paper will present further details of the satellites and the mission.

References

[1] http://articles.latimes.com/2013/jan/22/business/la-fi-mo-asteroid-miners-20130122

[2] http://www.lpi.usra.edu/meetings/acm2008/pdf/8293.pdf