COARSSS – Chain Of Autonomous Remote Sensing Small Spacecraft

Dorin Patru and Mihai Barbosu, Rochester Institute of Technology
Contact the authors at: dxpeee@rit.edu

All original text is italicized. Background image and not italicized text credit: NASA / JPL-Caltech - http://photojournal.jpl.nasa.gov/catalog/PIA17046

***A) <u>Motivation</u>**: Individual small spacecraft are handicapped in the exploration of space beyond Earth and Moon orbits due to the lack of a high gain antenna, i.e. a long range communication system.*

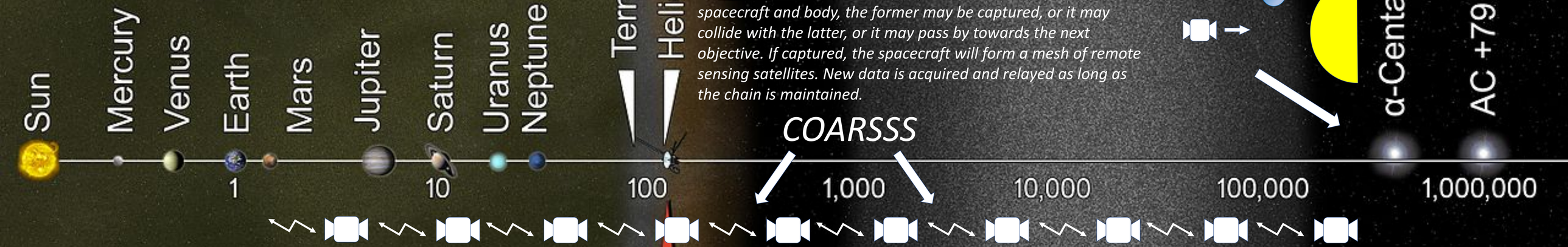
***B) <u>Concept</u>**: A chain of autonomous remote sensing small spacecraft would be launched sequentially in time from a location in earth orbit with an initial velocity equal to or greater than the earth escape velocity. The launch rate is chosen so that the distance between neighboring spacecraft allows inter-spacecraft communications. At the same time, this distance is chosen so that the size of the on-board communication system, including antenna and batteries, is minimized. This means that except for the last one launched, all other spacecraft in the chain will not have the means to communicate directly with "ground control", i.e. will have to operate completely autonomously.*

***C) <u>On Route:</u>** Each spacecraft in the chain acts as a communications relay, temporary storage, and optionally as a processing node. For fault tolerance purposes, the distance between every other spacecraft can be chosen so that in case the intermediate one fails, the data between the former two can still be transmitted at a lower rate. The object of exploration is reached successively by each spacecraft, and each acquires remote sensing data, e.g. images, and then relays these down the chain.*

***D) <u>Upon Arrival</u>**, depending on the relative velocity between spacecraft and body, the former may be captured, or it may collide with the latter, or it may pass by towards the next objective. If captured, the spacecraft will form a mesh of remote sensing satellites. New data is acquired and relayed as long as the chain is maintained.*

***E) <u>Exploration Targets:</u>** – using a fan sweep:*

i. *The Asteroid Belt → 0.5 – 5 AU*
ii. *The Kuiper Belt region > 100 AU*
iii. *The Oort Cloud > 1000 AU – only possible with an initial velocity of 1,000 km/s*
iv. *Alpha Centauri ~ 1 Mil. AU – only possible with initial velocities of 1-3% the speed of light – not feasible in the near future*



F) <u>Technical Approach and Feasibility:</u>

1) <u>Spacecraft</u>: Mass = 1 – 10 kg with two opposite horn antennas, a radio transceiver, and a sensor (e.g. a camera).

2) <u>Travel time</u> is a function of:

i. *The initial launch velocity of the spacecraft = 20 – 100 km/s*
ii. *And of the additional velocity increment that could be imparted by a small on-board engine. A Δv of a few km/s may be necessary for trajectory adjustments.*

3) <u>Communications</u> are a function of: path loss, which in turn is a function of distance, transmitter and receiver antenna gains, transmitter output power, receiver sensitivity, and transmission bandwidth.

i. *Distance between spacecraft = 3,000 – 30,000 km*
ii. *Carrier Frequencies = 1 – 5 GHz*
iii. *Horn antennas gains = 5-20 dBi*
iv. *Free Space Path Loss = 122 – 172 dB*
v. *This is well within current transceiver technology, assuming a transmitter power of 1-10 W, and a receiver sensitivity of 0.1-0.4 μV.*

4) <u>Launch Rate</u> is one spacecraft every 30 seconds – 25 minutes. This is a function of the initial velocity and the maximum allowable communications range.

5) The total number of necessary spacecraft and the time until the first one reaches the target:

i. *For the Asteroid Belt: 2,500 – 25,000 and 8.7 – 43.4 days*
ii. *For the Kuiper Belt: 500,000 – 5,000,000 and 4.8 – 23.8 years*
iii. *For the Oort Cloud with an initial velocity of 1000 km/s: 5 - 50 Mil. and 4.8 – 23.8 years*
iv. *For Alpha Centauri initial velocities of 1-3% the speed of light will be necessary – not feasible in the near future.*

6) The risk of failure is distributed over several tens or hundreds of small, identical spacecraft. The design, testing, and manufacturing of these will be able to take advantage of the economy of scale, a feature that few spacecraft can claim today. For example, assuming a cost per spacecraft of $100, 5 Mil. of these could be produced for $500 Mil.

7) An <u>attitude detection and control system</u> is necessary for remote sensing and antenna pointing purposes.

8) Continuous operation of the electronic data processing and communication sub-systems require a continuous source of energy – Radioisotope Power Generator (RPG).