On Discriminating CubeSats Launched Together

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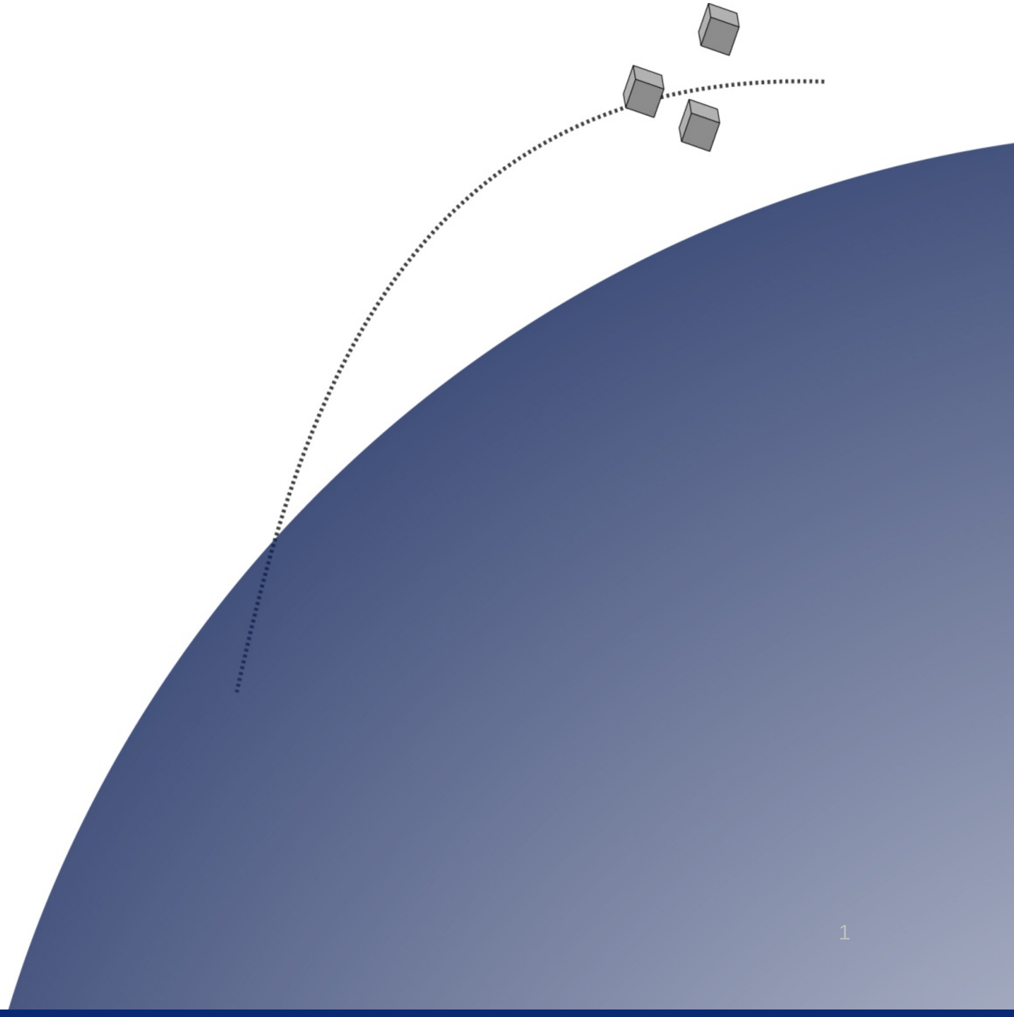


CubeSat Discrimination

Scope: Discuss and explore the problem of unambiguously identifying co-deployed CubeSat spacecraft with their object catalog numbers

Aim: Suggest a system concept that can be developed to provide an answer with little added difficulty for spacecraft design & users

Show: Feasibility of real hardware and system operation

A range of system design and hardware implementation choices remain for system development.

CubeSat Discrimination

Given: Multiple CubeSats deployed near simultaneously (for example from P-pods)

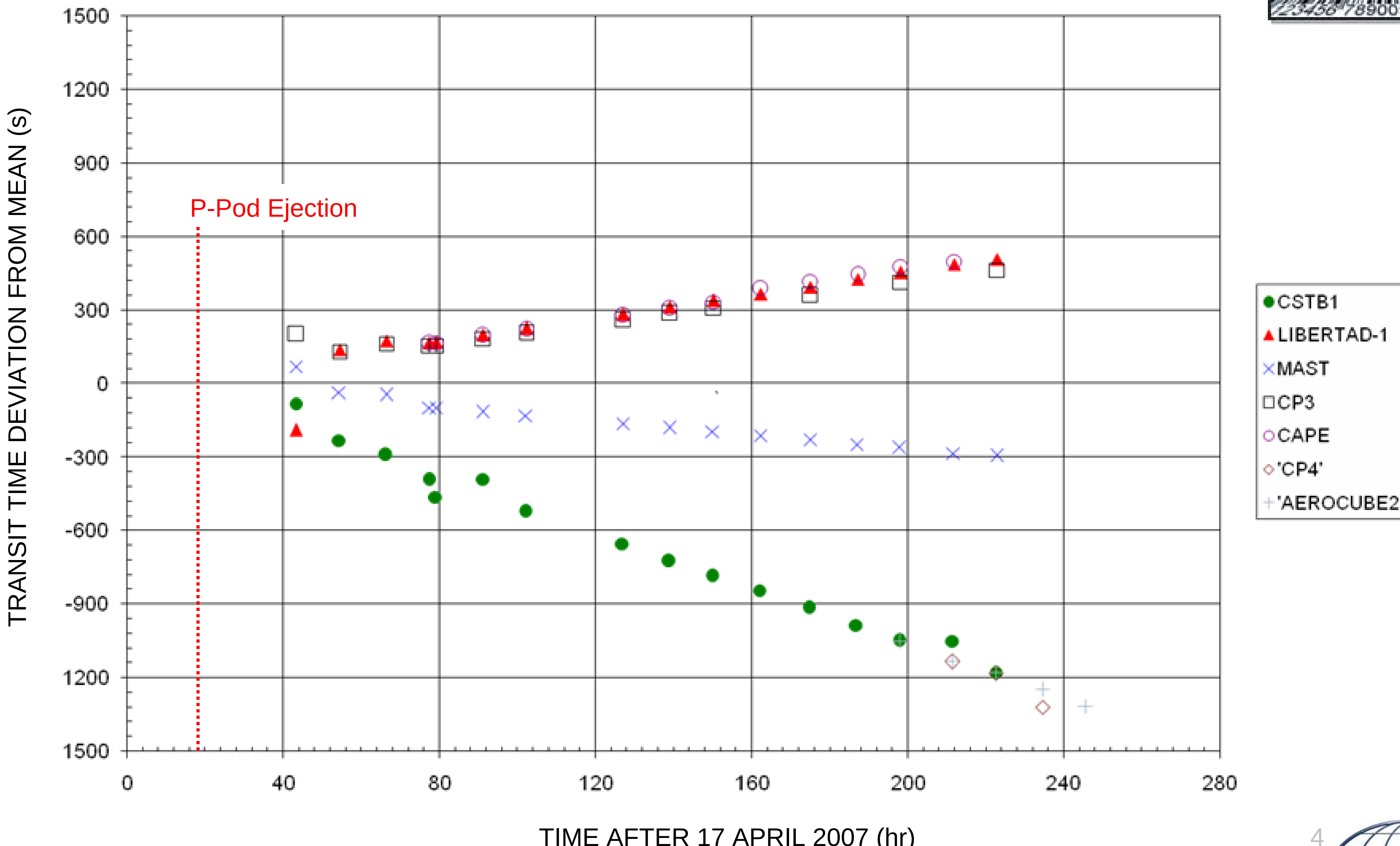
Result: Similar orbits of indistinguishable spacecraft

Question: Which are my CubeSats, which are yours, which are junk? Orbital elements at mission start are necessarily less accurate than later, identification of objects is unclear.

Operations with low gain (broad beam) antennae do not establish identity, leaving uncertainty; use of high gain (narrow beams) risky as well, but may establish identity.

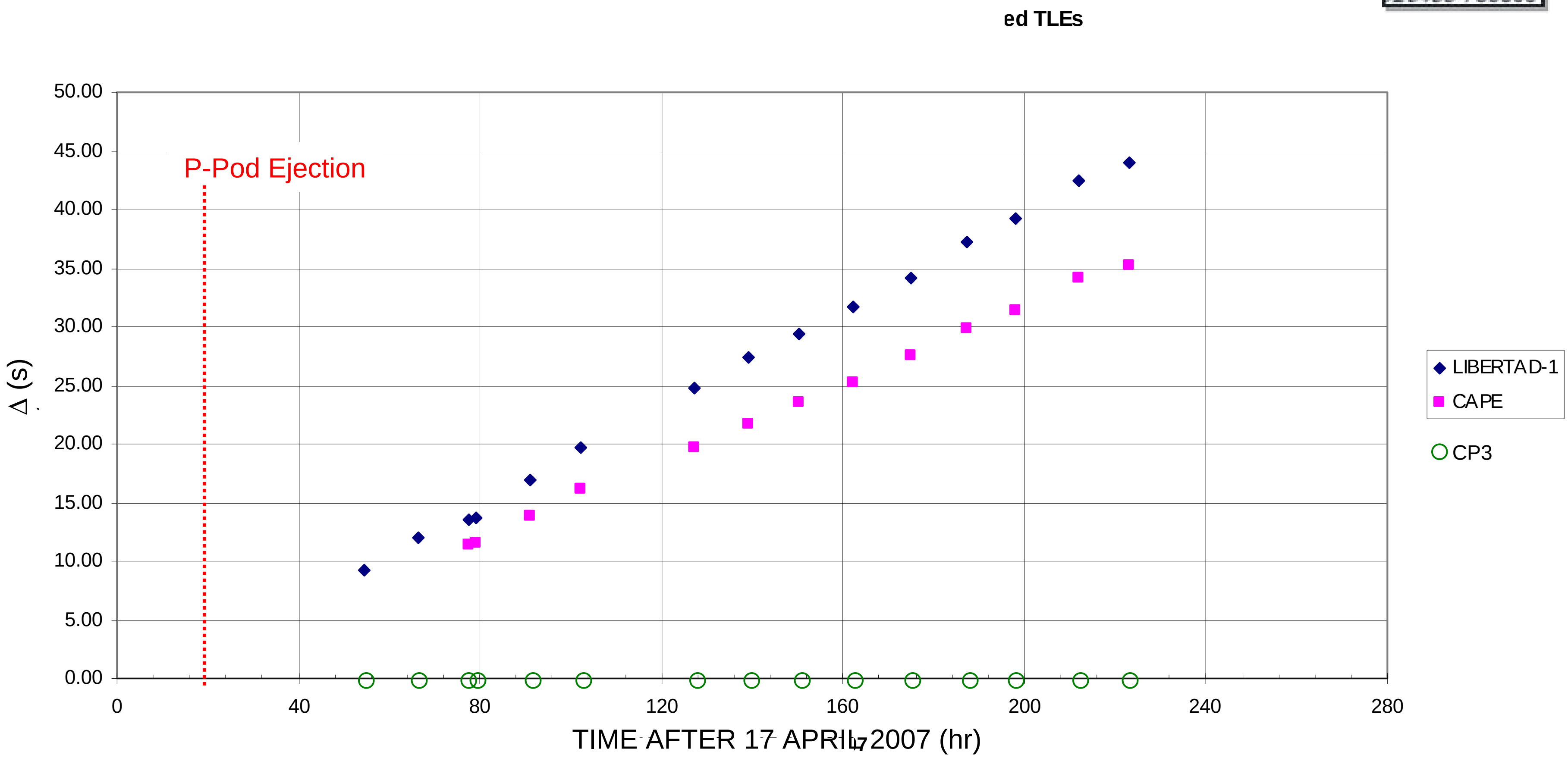
April 2007 DNEPR CubeSat Fleet

Transit times relative to mean from published TLEs



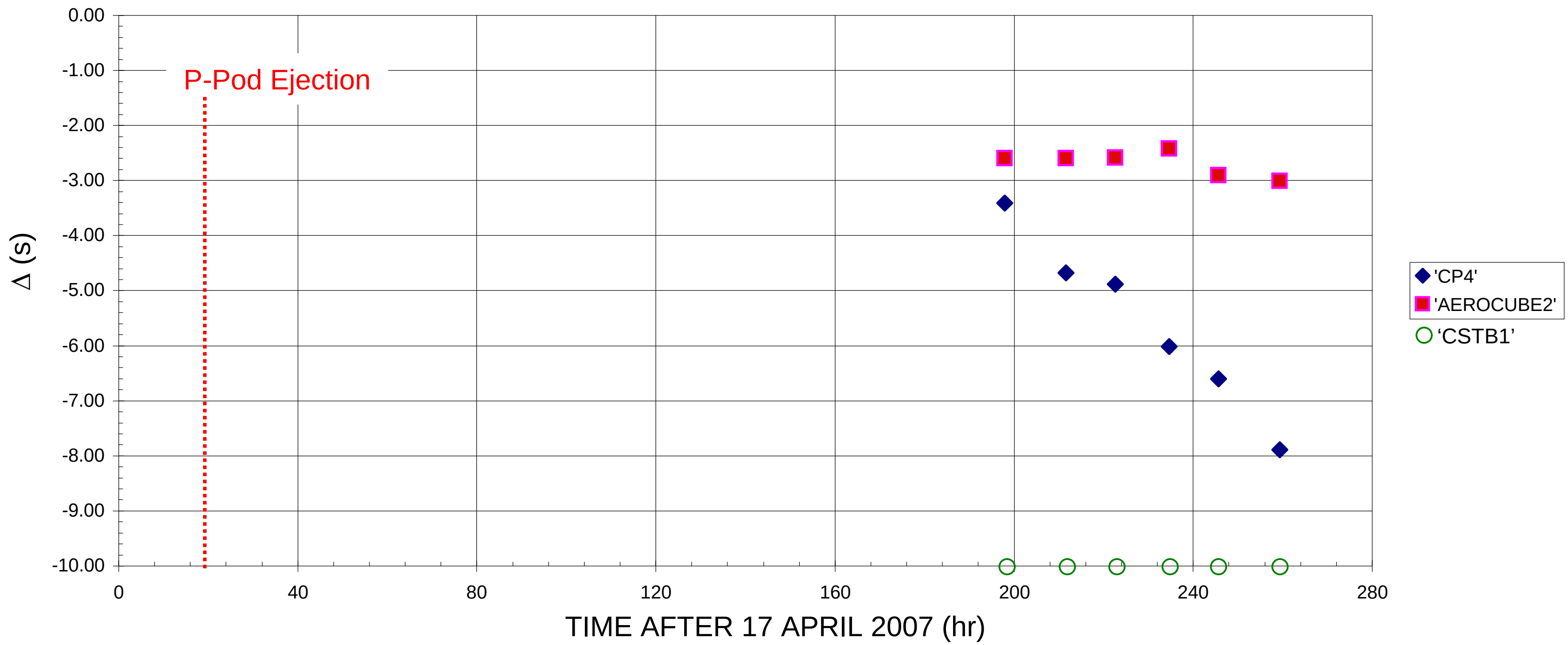
April 2007 DNEPR P-Pod B

Transit times relative to CP3 from published TLEs



April 2007 DNEPR P-Pod A

Transit times relative to CSTB1 from published TLEs



Approaches for CubeSat Discrimination

How to Identify:
Make them unique with labels

Need:
Read at a great distance, small to be useful

Possible Technology:
Optical, radio? Something like optical scanner or RFID tag.

Passive vs. Active:
Passive works by scattering (radar, lidar) R^{-4}
Active requires power source R^{-2}

Select:
Active RFID concept, detect fence (zero) crossing
Spacecraft Radio Identification Tag → ***SRI-Tag***

SRI-Tag System Concept

Erect an RF transceiver fence to stimulate a transponder equipped spacecraft and detect the response during crossing

– Similar to NAVSPASUR 216 MHz high power CW radar fence

Ground system operates like radar

-- Short messages addressed to particular spacecraft

– Time for response to each inquiry

-- Sited to serve common orbits

Place low power autonomous device on spacecraft

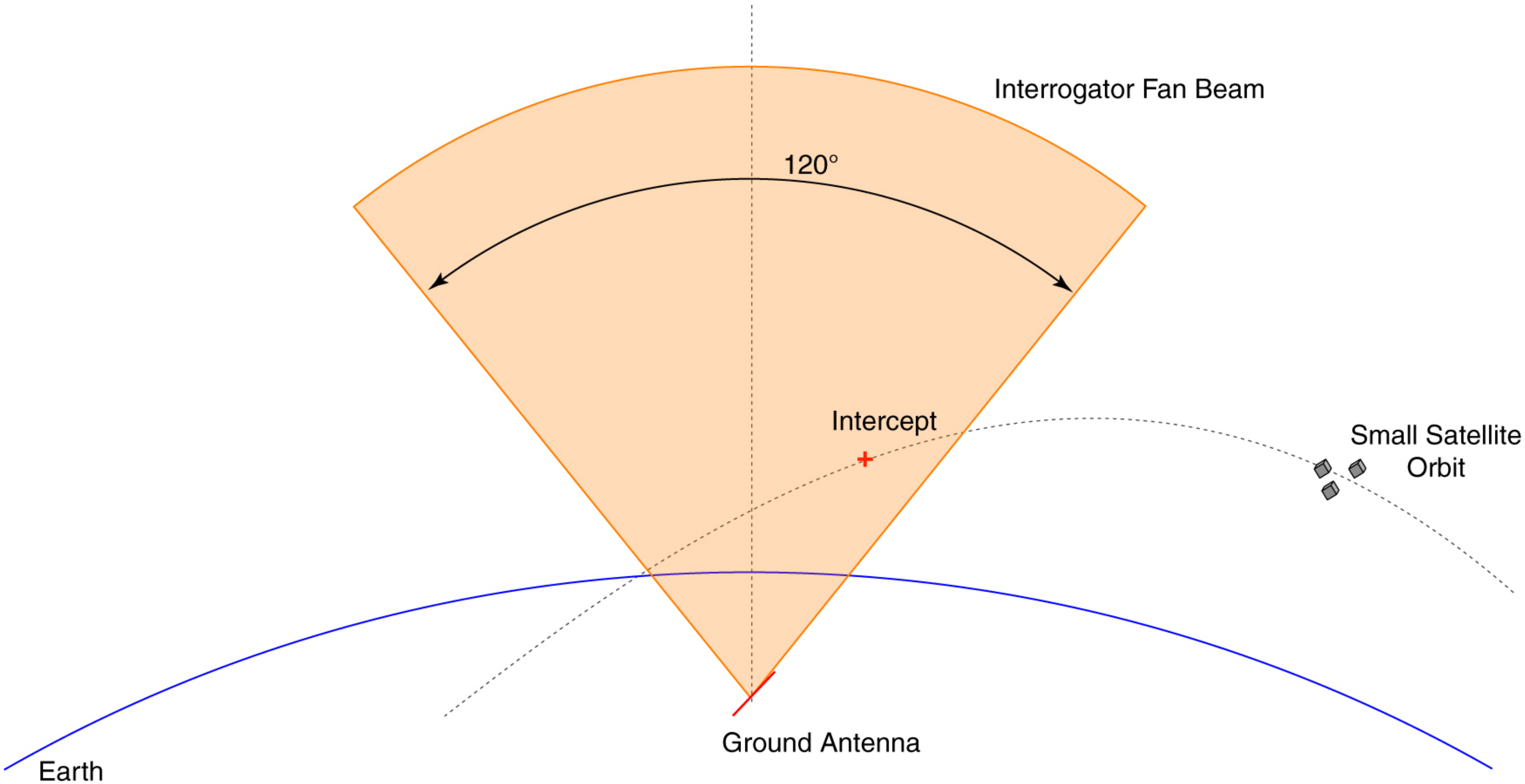
– Continuous listening for pulsed interrogations

– Short transmissions in reply

– Decoupled from spacecraft bus and power

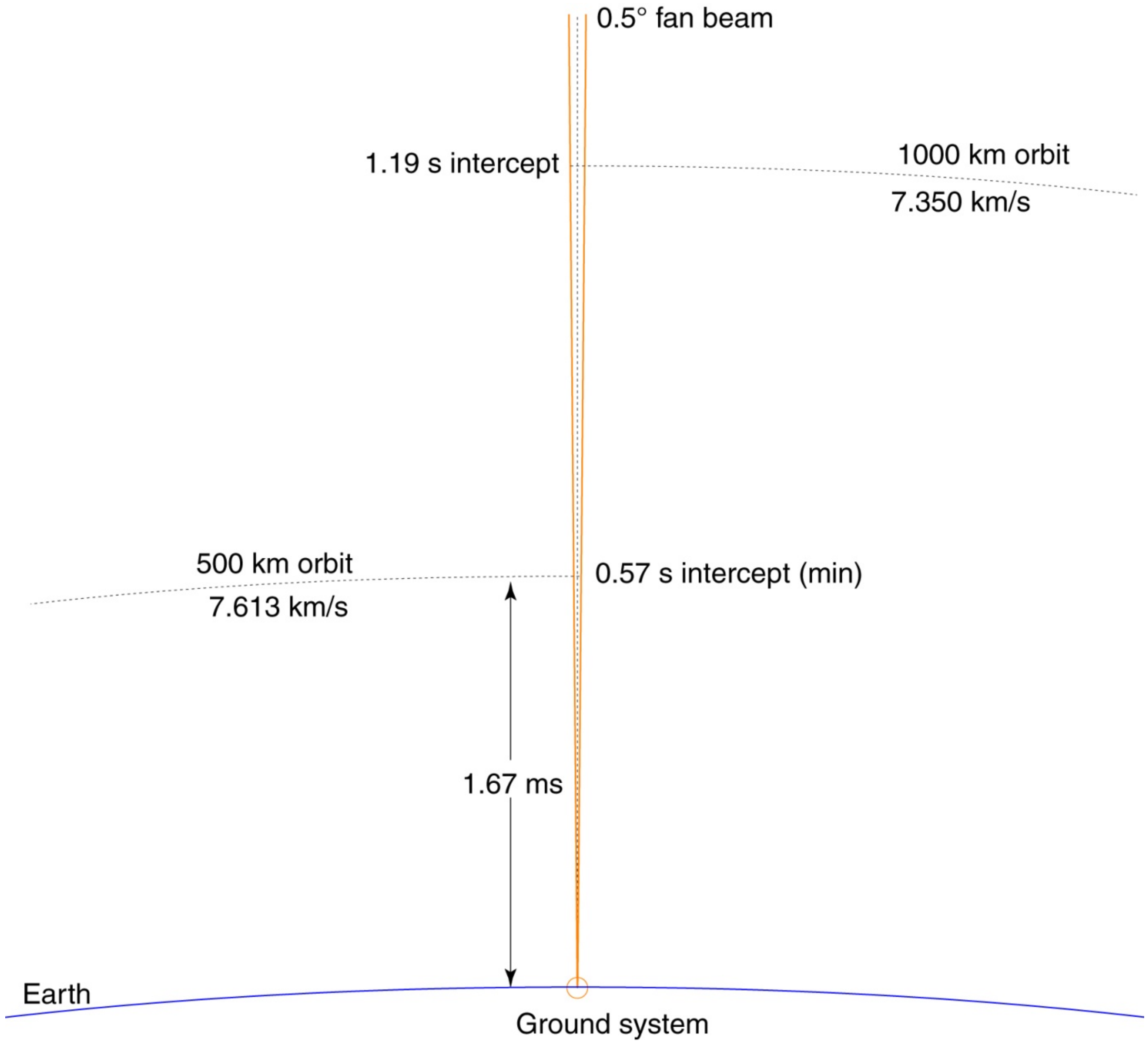
Use a frequency plan not interfering with other spacecraft ops [914 MHz ?]

Spacecraft Discriminating Concept– Fan Beam Fence

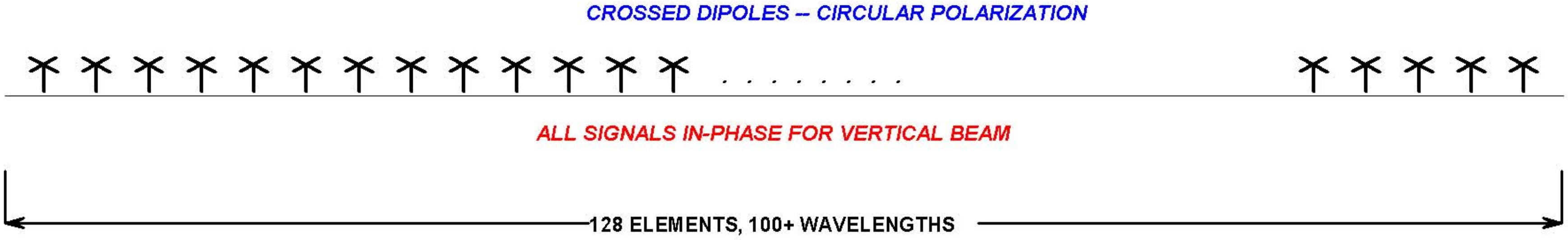


Azimuth orientation and geographic siting optimized for specific satellite orbits

Fan Beam Edge-On View Showing Spacecraft Transits



Conceptual Ground System
A Linear Array of Transmit/Receive Elements



Transmit Fan Beam Array:

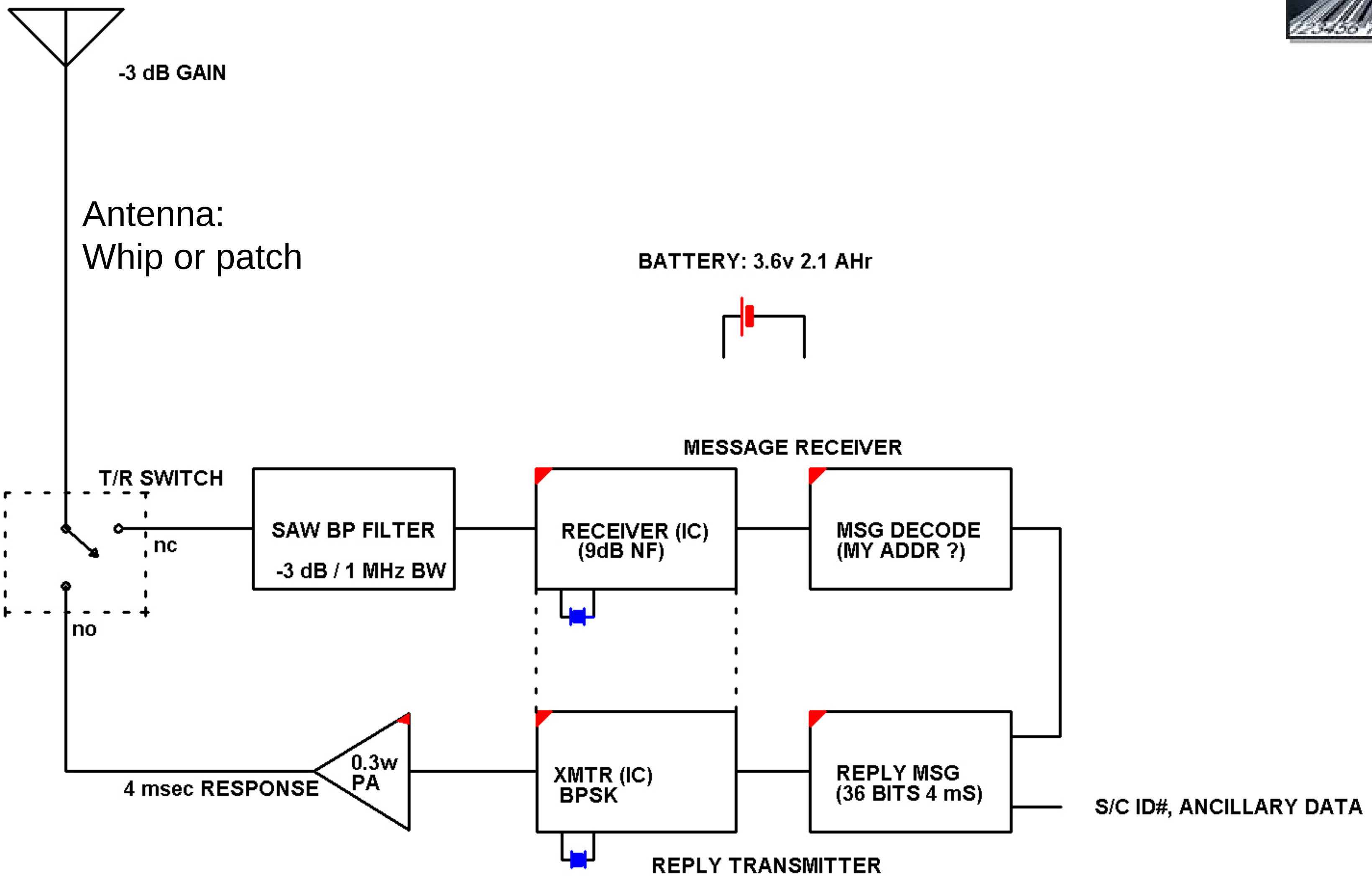
2 kW transmitted [16 W per element], 0.5° × 120° beam shape

Receive Fan Beam Array:

One LNA per element, 0.5° × 120° beam shape

Spacecraft Equipment

Possible Transponder Implementation



Ultra-Low Power RF Technology

SRI-Tag facilitated by existing implanted medical device and sensor network technologies

Recent advances reported, for example:

- "An Ultra-low Power 900 MHz RF Transceiver for Wireless Sensor Networks," Molnar, Lu, Lanzisera, Cook and Pister, IEEE 2004 Custom Integrated Circuits Conference
- "A Novel Power Optimization Technique for Ultra-Low Power RFICs," Shemeli and Heydari, ISLPED Oct 4–6, 2006

Power Estimate

Dominated by receiver operation, assuming:

3.6 Vdc, 1.2 mA continuous load

103.7 mW-hr / day

28.8 mA-hr / day

thus

2.1 A-hr AA size Lithium battery at ½ discharge

yields

36 days of operation.

An acceptable time for ID to be established and orbit to be stable,

if not

Add small solar cell trickle charge for extended lifetime.

Upward Link Analysis (test case)

Frequency, Wavelength:	914 MHz, 32.8 cm
Transmitted Power:	2 kW, 2 msec pulsed (63 dBm)
Antenna Gain:	20 dB
Path Length, Loss:	1600 km, ±156 dB
Polarization Loss:	3 dB
Data rate, modulation:	19200 bps, FSK
Spacecraft Antenna Gain, Temp	–3 dB, 300°K
Losses:	3 dB
Spacecraft Receiver Noise Fig:	9 dB
Signal at space craft Receiver Input:	–81 dBm
Link Margin:	22 dB

Downward Link Analysis (test case)

Frequency, Wavelength:	914 MHz, 32.8 cm
Transmitted Power:	0.3 W, 4 msec pulsed (25 dBm)
Spacecraft Antenna Gain:	–3 dB
Path Length, Loss:	1600 km, ±156 dB
Polarization Loss:	3 dB
Data rate, Modulation:	9600 bps, BPSK
Ground Antenna Gain:	20 dB, 300° K
Ground System Noise T:	140° K
Signal at Receiver Input:	–120 dBm
Link Margin:	5 dB

Interrogation and Timing

Transmit: 2 msec FSK coded enumerated message

Propagate to space craft at 2000 km: 6.67 msec

Activate transponder: <100 µsec, 4 msec response
BPSK 9600 bps

Signal return to ground: 6.67 msec

Overall time: < 20 msec

Interrogation rate: 50 Hz

If for example 5 CubeSats equipped with SRI-Tag pass through the fence simultaneously they can all be addressed 6–10 times

Summary

The SRI-Tag concept (a small transponder added to a CubeSat and associated ground system) can be employed to discriminate individual spacecraft due to ultra-low power RF technology.

The users / operators of small spacecraft and those responsible for identifying and tracking them (e.g., formerly NORAD) can benefit from the unambiguous identification of orbiting assets.

It is feasible to develop and implement such a system now.

Acknowledgements:

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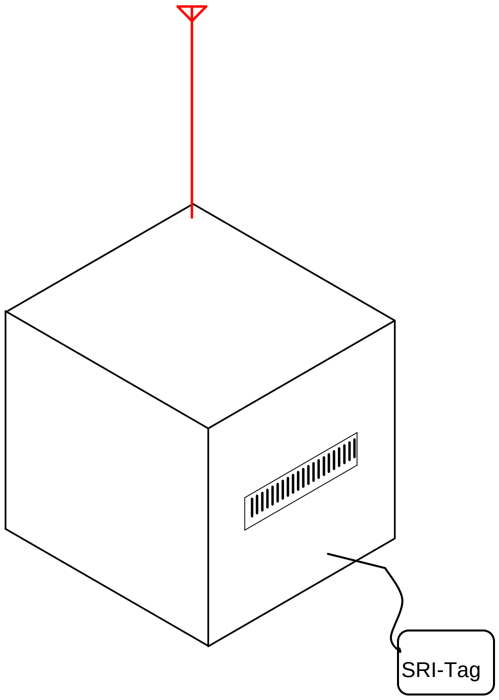
SRI-Tag