A MODEST PROPOSAL

(Yah!....Maybe....Why Not?)
You will Remember....

In Our Last Several Episodes...

We Built Bigger Small Satellites
Then Things Changed

• Universities Discovered They Could Build Really Small Satellites
• ....And Use Our Spectrum
• And Then the US Government (NRO, DoD, NASA, Etc.) Discovered Small Satellites
• And Then Came ITAR, with All of It’s Benefits to AMSAT
• And Now a 1 Liter Volume Ride to Space Costs $67,0000 (Average)
• NOT ENTIRELY GOOD NEWS FOR AMSAT-NA

SO, YOU WILL LIKELY UNDERSTAND WHY THIS THING GIVES SOME PRIOR AMSAT SATELLITE BUILDERS A RATHER UPSET STOMACH
However, As the Wise Man Said....

• If, in Your Back Yard All You Have is Lemon Trees....

Then You Make?                         OR

AMSAT Satellite MAKERS,
Being Ever Sensible
And Pragmatic...
Why AMSAT Should Submit a Proposal During this Cycle to NASA/ELaNa

Preliminary Thoughts on Advanced Amateur Satellite Communications Using a GTO 6U Format Cubesat System

Presented to AMSAT BoD
October 9, 2014

Ad-Hoc Satellite Technical Team *

* [Phil Karn, Jan King, Dan Schultz, Bill Tynan, Nick Pugh]
The Need

• It is important to place an Amateur Satellite into High Earth Orbit (HEO)
  – GTO option
  – Molniya option

• ELaNa has announced that it will be offering HEO opportunities, however, we now need to Compete with others also eager to go to HEO:
  – Starting Point for Cubesat Deep Space Missions
  – Others Want to Qaulify New Components in Higher Radiation Environments
  – Niche Market Communications systems want to launch
  – Others are Just Bored with LEO
Background

• About two weeks before this BoD Meeting, Dan Schultz N8FGV and Bill Tynan W3XO approached Jan King W3GEY with a rhetorical question:

  *Could a 6U sized spacecraft, carrying an amateur payload and launched into a Geostationary Transfer Orbit (GTO) have a performance that was at least as good as the AO-13 UHF-to-VHF Transponder?*

• This Presentation is the Outcome of that Inquirey
Physics Facts

• Limitations in such a volume-constrained design are, inevitably, limited by physical laws.

• Three factors come to our aid:
  – The RF performance (signal level) between a transmitter and a receiver, each employing directive antennas with a fixed (read constrained) aperture size increases as the square of the frequency.
    \[ S/N = K \cdot f^2 \]
  – The improvement of the performance of an uncoded digital signal transmitted using an optimum (matched filter type) modulation system (e.g. BPSK) can be improved to approach the Shannon limit. [As a practical matter BPSK, no coded at a BER of 10E-6, can be improved using coding by approximately 11 dB (theoretically 12.2 dB)]
    \[ S/N \rightarrow 11\text{dB with FEC} \]
  – The performance of GaN technology for use in SSPAs in currently advancing at Moore’s Law Rates
Other Helpful Technology Factors

• Development of Deployable Solar Arrays from Cubesat-Designed Systems is Advancing at a Rapid Rate.

• Three Axis Attitude Control System Component Designs are becoming Readily Available and are Much Cheaper:
  – Reaction Wheels
  – Star Trackers
  – Sun Sensors
  – Gyros/IMUs

• Rapid Prototyping Practices are Beginning to Enter Into the Small Satellite and Cubesat Arena.
Amateur Radio Factors

• We Investigated whether Analog Modes like SSB, CW and FM are Viable.

  **NO, NOT POSSIBLE**

• What Frequency Bands are Viable for say, 6U Cubesat Technology?
  – VHF and UHF
  – Lower Microwave
  – mmW

• What are the Constraints on Antenna Gain and High Power Amplifier Performance?

  **Must Fit Antenna INSIDE S/C**

  **Earth Size at Apogee → 17.4 ° = 19.8 dBi**

• How does Excess Path Loss Affect the Frequency Bands we are Allocated?

  **Water Vapor Losses in mmW Bands is JUST Acceptable**

• In the End, the Link Budget Rules – We must close the up and down links!!
Initial Thought Process

OSCAR-3, 5 and 6
Size Class S/C

≈

15 W DC

= 100 W EIRP >

AO-13, Mode B

≈ 50 W EIRP_{avg.}

→ 50 QSOs at a time

Launch:
$800K
Or Free
Via ELaNa

In GTO Orbit
A Complete mmW Transponder Concept

- 6U Cubesat
  - 10.45-10.50 GHz Earth Coverage Horn
  - 3.3 kbps
  - Voice
  - Data
  - Slow Video

- 24 GHz TX + Earth Coverage Antenna
  - 10 W GaN SSPA @ 24 GHz
  - 40 W DC

- 1 Meter Dish
  - GTO ORBIT

- Down Converter
  - Inside Unit
    - DeMUX & FEC Decoder
      - VK5DGR Codec-2
      - Ettus USRP B200 SDR

- SDR
  - 10.5 GHz TX
  - 1.8 W

- Turbo Coded Link
  - ≈ 0.5 Mbps

- 3.3 kbps

- 300 Users = 150 QSOs if Simplex
OK, OK, OK...We’ll Do It

• Every Orbit Has a Perigee

• And Every Satellite Needs a TT&C Link

• So...

  Telemetry Link at 435.XXX MHz
  • 1 Watt
  • Monopole Antenna

  Command Link at 1269.XXX MHz
  • 1 Watt
  • Patch Antenna

  Linear Transponder
  50 kHz Bandwidth
  • 1268 MHz Up
  • 436 MHz Down
  • 1 Watt (Additional)
  • Same Antennas

  TT&C +Transponder Size < 100 cm²
  < 5 Watts with Xpder ON

  Only Used Below 5000 km
  Orbit Altitude
Let’s Get Specific – A Point Design

• 6U CubeSat

• 3-Axis Stabilization System Required (About 1° Accuracy in 3 Axes)

• Deployable Solar Array (Up to 72 watt systems available; need about 50 watts)

• Transponder/Payload
  – 10.45 to 10.50 GHz uplink and 24.0 to 24.05 GHz
  – 19.8 dBi Gain (Horn Antenna Technology) both Uplink and Downlink
  – 10 watt S/C SSPA (Transmitter Power)
  – 120 K LNA Preamp
  – Contention Based FDMA (sort of) Uplink (Random Channelization Plan)
  – Higher Speed (500 kbps to 1 Mbps) downlink
  – Intensive (indeed Maximum Use) of FEC
  – Supports up to 300 users (or QSOs) at 3200 bps
  – Supports up to 100 users (General Utility) at 10,000 bps

• Other Smaller Hosted Payloads Can Be Accommodated - IMPORTANT
What About the Ground Station?

• Yes, it must be a digital design as well.
  – Work of VK5DGR Codec-2 and ARRL Recognition is Evidence of Growing Interest
  – SSB provides insufficient processing/coding enhancement
  – Digital Technologies likely particularly attractive to younger radio amateurs
  – The likely best approach is a kit-like system developed by AMSAT as part of the program

• The RF Characteristics Proposed:
  – 1 meter dish with wide band feed (10 GHz to 24 GHz)
  – 1.8 to 20.0 target power (10 watts fallback)
  – 24 GHz preamp – down-converter (LNB)

• Where might Radio Amateurs Obtain Such Hardware:
  – Normal Distributors (e.g. Down East Microwave)
  – Overseas Distributors (ITAR Restrictions Apply) (e.g. Kuhn DK6KQ)
  – Kit Systems Configured from Off the Shelf Boards
  – As allows – Roll Your Own
How to Address the ELaNa Proposal

• Submitting a Proposal Does Not Obligate AMSAT to Perform the Mission*

• The Proposal MUST support the NASA’s Strategic Plan.

• We will Complete the Proposal ON TIME including the Pre-Review Requirements. The Manpower is available among the participants.

• Areas where we could show support of NASA’s plan:
  – Educational Development Based on Unique Characteristics of Communication Orbit and Water Vapor Excess Path Loss Physics (Education and Training of the Engineering Workforce)
  – Education Value of High Quality Communications System – Similar Concept to ARISS program but, with different end objectives. (e.g. School-to-School Com Under NASA)
  – Advancement of Critical New Technology: Ka-Band is of strategic importance to the Small Satellite Community – Ultimately, Small Satellites will completely replace Large remote sensing missions. We can continue to advance this technology via our work on GaN SSPAs.
  – Investigation of the properties of GTO orbits applicable to Cubesat and Smallsat Systems (space science).

• Review Team Names Put Forward:
  – Dr. Franklin Antonio (QCOM)
  – Dr. Al Katz, K2UYH (Trenton State University)
  – Dr. Bob McGwier, N4HY (Virginia Tech)
  – Dr. Jammie Cutler (U of M)
  – Dr. Andy Viterbi (No Introduction Necessary)
  – Dr. Paul Shuch, N6TX - SETI

* See Next Slide
ELaNa Statement

"The CSLI results in a list of selected CubeSat missions in priority order. Using the priority list as a guide, and dependent on the readiness date and orbit requirements gathered from the proposals, LSP manifests CubeSats on missions as opportunities become available. Once manifested, the CubeSat team is notified to determine if the selected orbit will meet the requirements of the CubeSat mission. If it is determined that the orbit is not acceptable or the CubeSat mission will not be ready in time to support integration, the next mission on the list is then contacted."

source: "ELaNa - Educational Launch of Nanosatellites", Garrett Skrobot, SSC12-V-5
University Affiliations  
(Science & Engineering Partners)

- Robert Reed of Vanderbilt expressed interest, will help write proposal as they did with Fox-2

- Wesely Powell at Goddard is looking at possible technology demonstrations.

- There is much interest in lunar CubeSat missions at Goddard and there should be opportunities for TRL demonstrations to support those missions.
Teledyne requests that the Micro Dosimeter data be made available to The Aerospace Corporation for the purpose of improving space environment models used to predict radiation dose with the multitude of Micro Dosimeter data obtained from orbits.
"Orbital environments other than GEO and LEO/Sun-Synch are poorly monitored, leading to large uncertainties in anomaly assessment and spacecraft design specifications. A successful strategy for deploying comprehensive sensors would provide similar coverage for other widely used orbits while also preparing at least preliminary climatology information for arbitrary new orbits."

"In order to enable updates of the radiation specifications, comprehensive sensors should be flown in every critical, commonly used orbit (e.g., GEO, Highly Elliptical Orbit [HEO]/Molniya, Medium Earth Orbit [MEO] and LEO) and on path-finder missions. In addition, comprehensive sensors can be of high value when flown on 6 elliptical orbits, especially those with low inclination (e.g., Geosynchronous Transfer Orbit)"

Source: "Targeted and Comprehensive Space Environment Sensors: Description and Recommendations"

Los Alamos National Laboratory report LA-14381
Anticipated Project Cost/Price

• **Space Segment:**
  - Reaction Wheels (3): $45K
  - Star Tracker (1): $45K
  - Flight Computer (1): $5K
  - Solar Panels: (2 SAWs): $50K
  - Machined Components: $20K
  - Propulsion (?): $0K
  - Wire Harness (Connectors): $25K
  - Ka-Band SSPA: $25K
  - SDR Stuff: $5K
  - Machined RF Parts: $5K

  __________

  $225K

  — 6U Launch Cost (For Reference): $450K (Via ISIS as a secondary launch service provider)

• **Ground Segment:**  Target Price: $1,000