Advanced Communications Package

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ACP Vision

- Create a payload ***and matching ground segment*** for Eagle which will:
  - enable new ham radio applications and activities
  - be accessible to hams not already on satellites
    - Low cost
    - Small, simple, CC&R-friendly antennas
    - Interesting uses and applications
  - Provide emergency communications capabilities superior to what the pros have

Vision, cont'd

- Investigate technologies for future missions
  - Continuously available worldwide constellation
- Create flexible systems usable terrestrially
- Complete ground stations available ***before*** launch
  - one stop shopping
- Flexibility
- Have fun

Not Part of Vision

- Allow users to reuse AO40 (or other) equipment
- Analog Modes
- Transponder
- Yet another “big-guns only” system
- Internet replacement
- Build your own ground station
- Any particular band or technology

Capabilities

- Send bits up and down
- System shouldn't care what they represent (Audio, Video, Photos, Data, etc.)
- Asymmetric up/down links
- Scalable data rates to enable different classes of users stations

ACP

- S2-Band (3.4 GHz) Down, 10 MHz wide
- C-Band (5.6 Ghz) Up, 20 MHz wide
- ~~~43 Patch antennas for each band~~
  - ~~Phased Array, steered Digitally~~
- Small Dish, of appropriate aperture to illuminate the earth
  - Compromise between the 2 bands if 1 shared dish/feed
- Software Radio Digital Comms Hub
  - Digital Voice (4.8kpbs), up to 500 channels!
  - Digital Data (2.5Mbps peak)
  - Only multiplexing and maybe QoS
    - state, intelligence, apps in ground stations

Data Rates

- Class 1
  - ~500 bps up
    - 1.2 kbps digital voice in bursts, a la Nextel
    - Data, telemetry, APRS, paging, etc.
  - 50 kbps down to mobile stations
    - Full digital voice, data, telemetry, etc.
- Class 2
  - 100 kbps up, 2.5 Mbps down to small fixed stations
    - High quality digital voice, data, digital video, etc.
- Satellite apportions downlink capacity dynamically
  - Class 1 and Class 2 can talk to each other

Class 1 - Handheld

- Useful for
  - emergency comms, demos for schools,
  - autonomous data collection
  - weather, terrestrial telemetry
  - HT-like apps
- 1W TX power
- Small antennas, hand-pointed
  - no more than 8-10 dB gain
  - Patch? helix?

Class 2 – Small Fixed

- Useful for
  - Emergency command stations
  - Video
  - High quality digital voice
  - General bulk data transmission
- 5 Watts TX power
- Small, inconspicuous antenna
  - 2 Foot dish
  - Easy to aim, wide beamwidth

Note...

- All data rates are based on the following
  - Geosync orbit
  - 200W Satellite TX Power
  - 5dB required Eb/N0
  - KA9Q's path loss spreadsheet
  - Lots of back of the envelope calculations, approximations, guesses, etc.
    - Most system parameters still unknown

Uplink

- Unfiltered BPSK, possibly with residual carrier
- FDMA
  - Many (hundreds) of uplinks demodulated in parallel
  - Enough uplink bandwidth for everyone to get their own frequency
    - Uplink frequency assignment a combination of random and Least-Recently Used (LRU)
    - All users uplink at whatever rate they need and for which they have the power and gain (no class 1 or 2 distinctions)
- Conventional convolutional code + Reed-Solomon
  - Could use turbo code, but demod is expensive

In-Satellite Processing

- Demodulate, decode
- Minimal state, packet interpretation, or policy
- Basic packet prioritizing, QoS
- Most policy stuff handled in ground stations
  - Satellite doesn't care who is talking to whom
  - Just reflect bits
- Encode, Modulate

Downlink Multiplexing

- One signal with multiplexed data
  - Single carrier
  - Can still proportion power and coding differently
    - Give signals going to small users more time (power)
    - Prioritize traffic
  - Simple TX amps and modulators
  - Users can receive multiple streams easier

Downlink Modulation

- ~~We have more bandwidth than we can use~~
  - ~~Narrowest band under consideration is 10 MHz~~
  - ~~We should use as much bandwidth as we like~~
- We are power limited (maybe...)
  - Peak transmit power limited by devices
  - Total consumed power limited by ~~solar array~~ hosts
- We should use a modulation system with a constant envelope to enable the most efficient use of our energy
  - Can use a Class-C or Class-E amp
    - Unless we have more power than we need. Then we should be linear with RRC filtering for sidelobe suppression...

Downlink Modulation, II

- 5 Megasymbols per second unfiltered BPSK
  - Results in sidelobes outside satellite band...
    - If main signal is weak, no need to worry about sidelobes
      - Not so weak anymore...?
  - Constant envelope, Power efficient
  - Easy to demod, Coherent reception
  - Used by GPS satellites

Downlink Coding

- Turbo Coding (or turbo + RS)
  - Code Blocks of 1800 bits
  - Multiple voice (or other low rate) streams combined into single blocks
    - Lower latency – don't have to wait for a full block
    - Pad with telemetry, or repeats of data
- Code blocks preceded by one of two sync codes
    - “This is a new block” OR
    - “This is a repeat of last block”

Downlink Coding, II

- Class 2 users
  - Rate ½ code (3600 symbols/block)
  - Blocks intended for Class 2 users sent once
  - Max capacity ~2.5 Mbps (5Msps / 2)
- Class 1 users
  - Rate 1/6 code (3 blocks of 3600 symbols)
  - Blocks intended for Class 1 repeated ~16 times
  - Max capacity ~50kbps (5Msps / 6 / 16)
  - Class 1 user can have an ~18dB worse antenna
    - Power gain of ~17dB (48x) vs. Class 1
    - Coding gain of ~1.2dB vs. Class 1 (rate 1/6 vs 1/3)

Important Unknowns

- Power input budget
- Heat output budget
- Allowed antenna space
- Pointing accuracy and stability
- Frequency reference? Do we need to fly our own?
- Data/control/telemetry bus to rest of satellite?
- Can we REALLY transmit on S2?
- Citizenship requirements of team members?

Design Partition

- Antenna[s]
- Receive Chain
  - RF to samples
- Transmit Chain
  - Samples to RF
- Core digital system
  - Demod
  - Multiplexing and control
  - Mod

Major Tasks
Overall System Design

- Link Budget and capabilities analysis
  - Done by April 30
    - Given that we finally get some answers about parameters
  - Ettus, Karn, McGwier, Clark, ground station team
- Modulation and Coding Design
  - Done by June 30
  - Ettus, Karn
- Complete System Simulation
  - Done by August 31
  - Ettus, Karn, other volunteers (?)
- Over-the-air Protocol Design
  - Done by Oct 31
  - Ettus, Karn, Brickle (?)
- Continuous communications w/ground station team

Major Tasks
Antenna System

- Decide on separate vs. shared apertures
- Estimates of space and ground antenna performance
  - Gain, Pattern, polarization, ground antenna sidelobes
  - Done by March 31st so Link budget team can complete by April 30
  - Tom Clark?
- Aperture and Feed design and complete simulation
  - August
  - ?
- Mechanical Design, mounting, etc.
  - December
  - ?

Major Tasks
Receive Chain

- Determine Filtering and Shielding Requirements
  - Does the the of the satellite blast us on any particular frequencies? How badly?
  - April
- Overall performance estimates
  - Dynamic range, noise figure, phase noise, etc.
  - April so Link Budget team can finish
- Overall signal chain architecture design, choose IF/baseband, LOs, gains, etc.
  - May
  - Hodgson?, Ress?
- Identify components for actual payload, design, build, debug ~5 prototypes
  - September

Major Tasks
Transmit Chain

- Choose space implementation technology
  - TWTA? SSPA? Design or buy?
  - Architecture team will provide linearity requirements by April
  - Preliminary performance specs by April
  - Choice of direction by June
- Overall signal chain architecture
  - IF/BB, Los, gains by June
- Identify actual components to fly
  - August
- Design, build, debug ~5 prototypes (not including expensive final amp) by Sept
- Final amp choice by December, 1 prototype

Major Tasks
Core Digital System

- Specify Interfaces to TX and RX Chains
  - April
- Research space-capable FPGA options
  - May
- Identify Prototype Platform
  - Lyrtech? USRP2? Other? Design our own?
  - April
- Preliminary hardware design for actual payload
  - November
- Logic and firmware designs for prototype systems
  - So we can test with ground station team in SD
  - December