Making CubeSat Comms Mission Flexible and Provide Schedule Relief
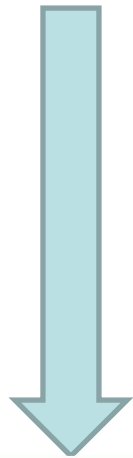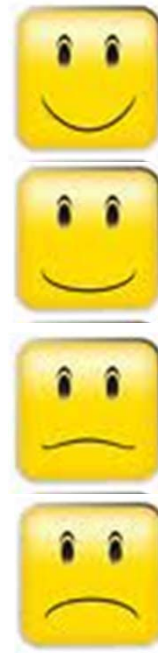
AstroDev

Kevin Brow

www.astrodev.com

The Problem

CubeSat missions on short timeline <12 Month

1 Semester Training
1 Summer Designing
1 Semester Building
? Time Testing

How do we ensure success?

COTS but software driven

- Move functionality into COTS
  - Incremental, Commonality, Maintenance

- Keep flexibility for changes later
  - Updates in installation

Radios are the gateway into your spacecraft.

The Radio

- Generally everyone thinks of a radio as rigid. **Not the case!**

  – Protocol is modifiable

  – Latest RF front ends are data rate, modulation, frequency flexible.

  – "Software Defined Radio" not required.

Hardware Engineer
$50/hr

*With all the flexibility comes disadvantages

Software Engineer
$150/hr

The Radios

Break open in a limited but flexible way

- Too much flexibility causes huge manuals!

New Options:

- Beacon and Ping
- Reset Backdoor
- Telemetry
- Dynamic Link
- Flight Software Update

Beacon

- **Beacon**
  - **Interval: Flexible interval with dead period**
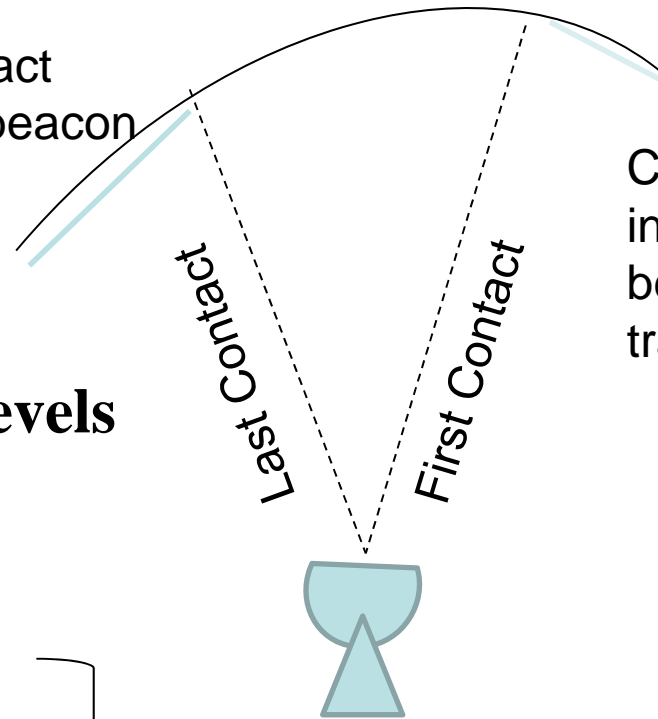
  - **Ping:**
    - **Echo at radio level**
    - **Query spacecraft levels**

  - **Contents:**
    - **User defined data**
    - **Radio telemetry data**

Post contact
return to beacon
level

Can't save on
initial contact
beacon in
traditional systems

Last Contact

First Contact

Restrict to 256 bytes for HAM band
<250 ms @ 9.6 kbps   pre/post CW?

Beacon: Ping

Ping/Wakeup:

- **Fast response time**
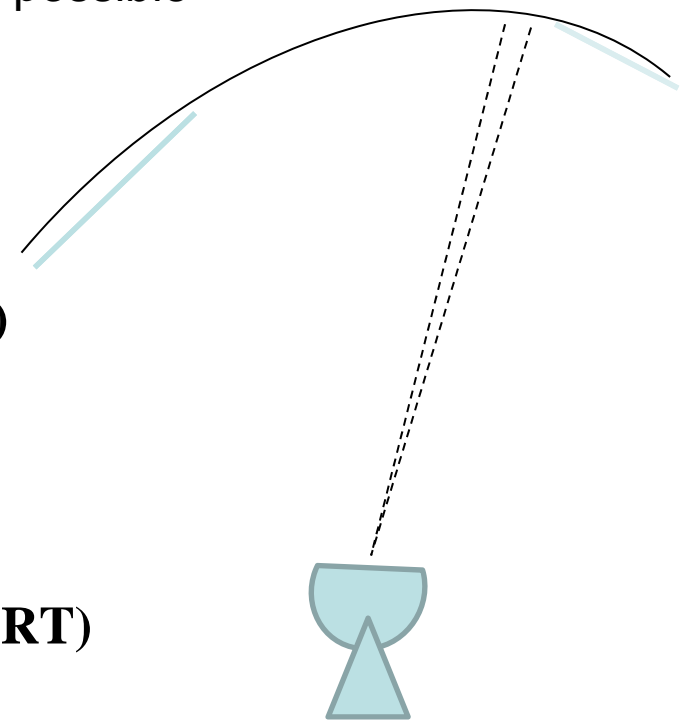- **Minimal packet**

Ground Station:

- **25 ms (CW)**
- **25 ms Data (10 Byte Key + 20 Byte Overhead)**
- **Listen**

Spacecraft:

- **50 ms (Modem)**
- **75 ms (CRC, Key, Form Response, Notify UART)**
- **100 ms (Amp Ramp Up)**
- **25 ms Data (14 Byte Telemetry)**
- **50 ms (Amp Ramp Down)**

Active Approach to Locating Sat
Started by ground station, try to
become as close to transponder
as possible

The Amazing: Reset

- **Watch dog output**
  - **What do we really want here?**

    Not just radio processor trigger, low level RF.

Tap In Here

Pre Amp

RF Processor ↔ Front End

Power Amp

SW — ANT

Tap In Here
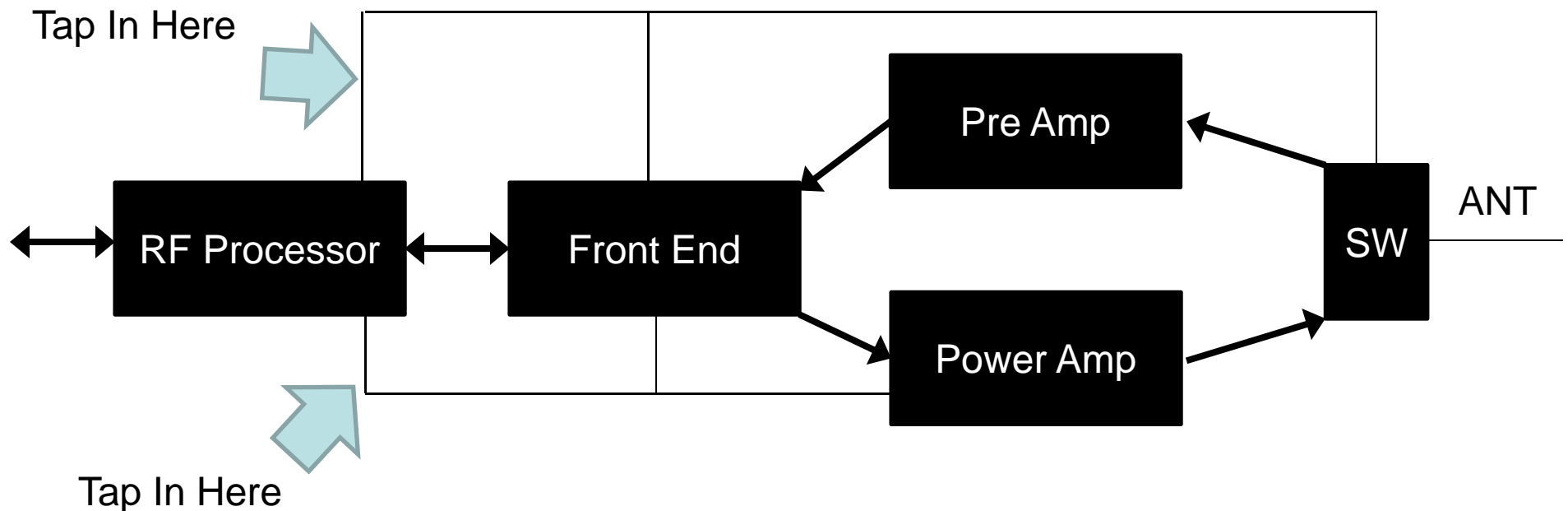
Reset Cont.

- **Satellite backdoor reset**
  - **Key: 64 Bytes loaded by user**
  - **Toggle I/O line as defined**

- **Subsystem keep alive**
  - **Radio generates clock signal, spacecraft watchdog**
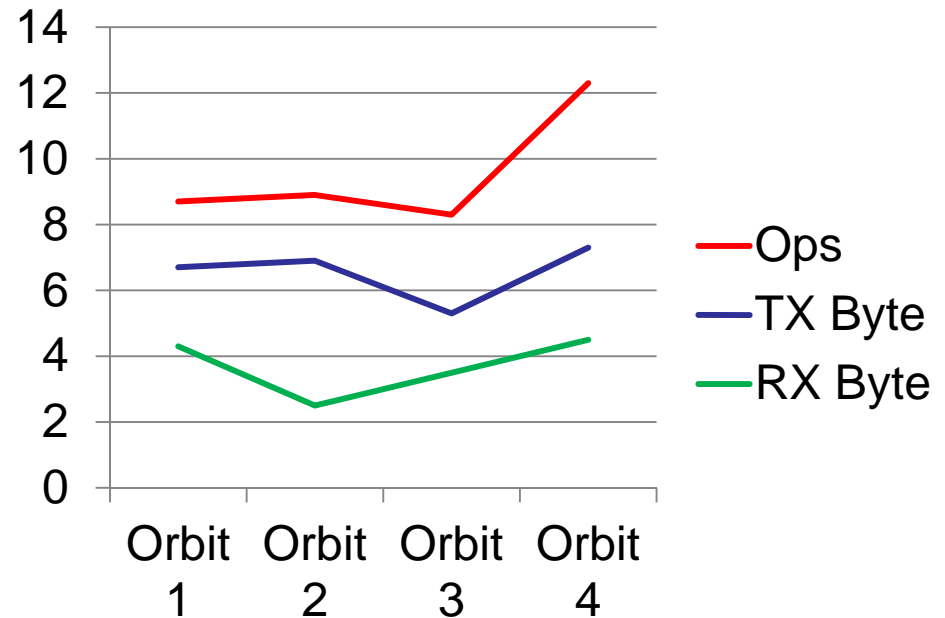 - **Radio toggles on TX, RX, timer, etc.**

Telemetry

- **Log Telemetry Packets**
  - **Historical On/Off**
  - **Performance**
  - **Environment**

- **Radio Information**
  - **Byte RX count**
  - **Byte TX count**
  - **Temperature**
  - **RSSI**
  - **Operations count**
  - **Tick count**

Dynamic Link

Fast Settings: Quick adjustment of RF settings allow power savings.

- **Power amplifier adjustment/Ramp**
  - **DC Draw = Save Power**
  - **Continuous data stream**
- **Data rate**
  - **9.6/19.2/38.4 kbps**
 - **Very complex, not for everyday use**

Radio FSW Update

- On the ground or in space we constantly battle the firmware revision state at the last few weeks before delivery.

- It is imperative that the radio can be flashed from either side, Satellite or ground station.

- Query software build info
- Store packets until complete
- MD5 and Key
- Verify
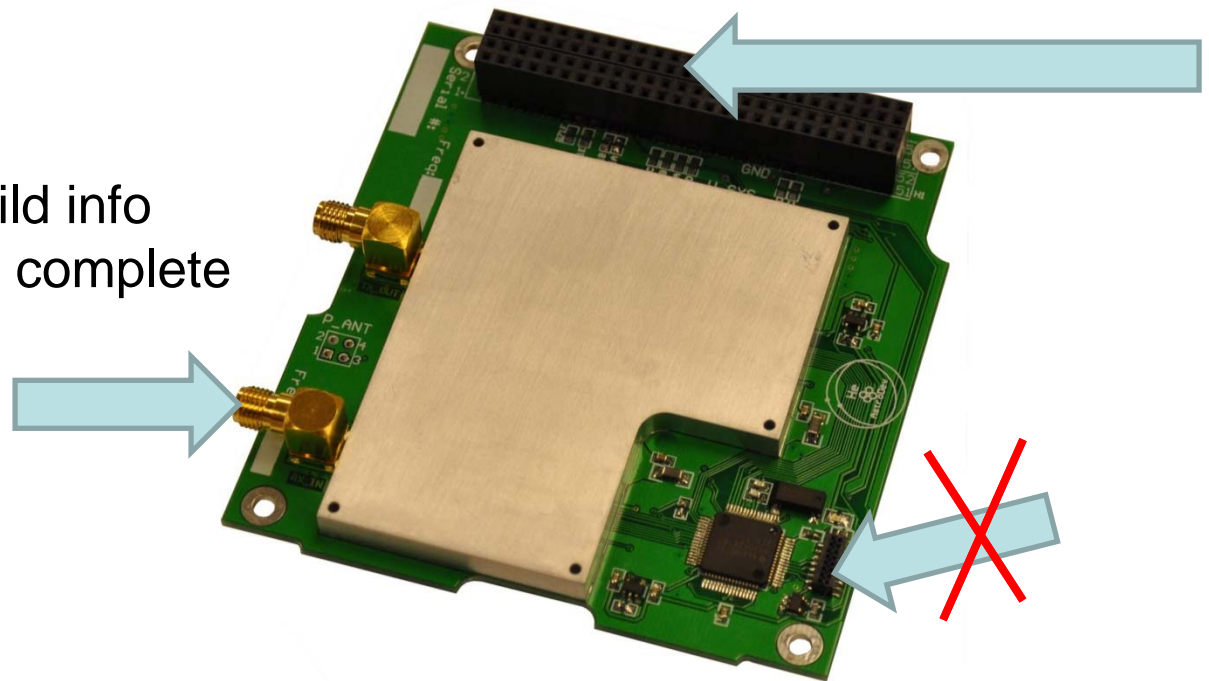
Radio FSW Update

Memory Map

| ROM BSL	Image A	Image B	Telemetry Storage	V e c
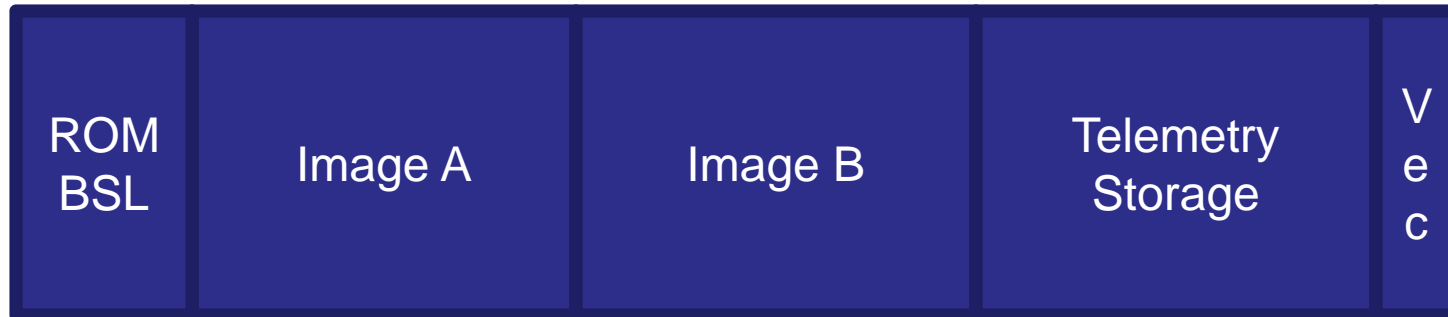
- Query: Revision number, Image A & B
- Store packets: 50 kB of Flash reserved for each image
- Command: Switch BSL entry location, cause reset
- Verify: Detect proper boot and notify (Delay, return to other Image)

Radio FSW Update

So what does this mean?

- The Satellite C&DH system can have the radio flight software stored in protected memory

- The ground could recover an entire mission as long as there is power applied to the radio RX

Diode

LDO

SolarCell

Radio (0.1 Watt)
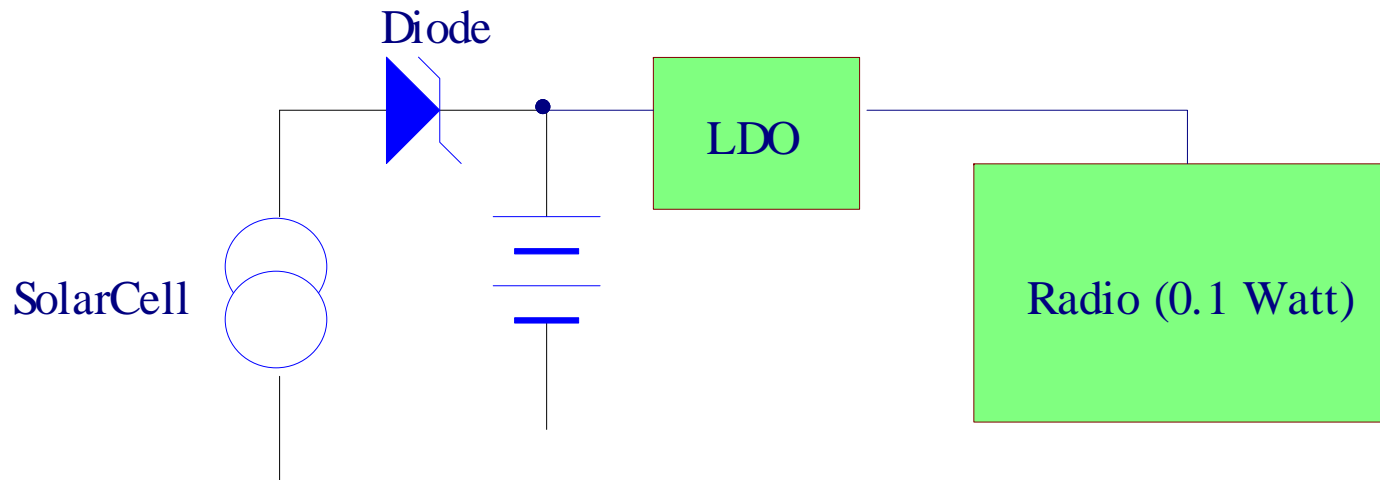
Conclusions

- **Cosmic X Ray Background NanoSat**
  - **Contained first test of on the fly FSW update, telemetry log, ping, and back door.**

- **We can add flexibility as far as we can stand to maintain it.**

- **All these functions are being loaded into AD He-100 and Li-1 Radios**
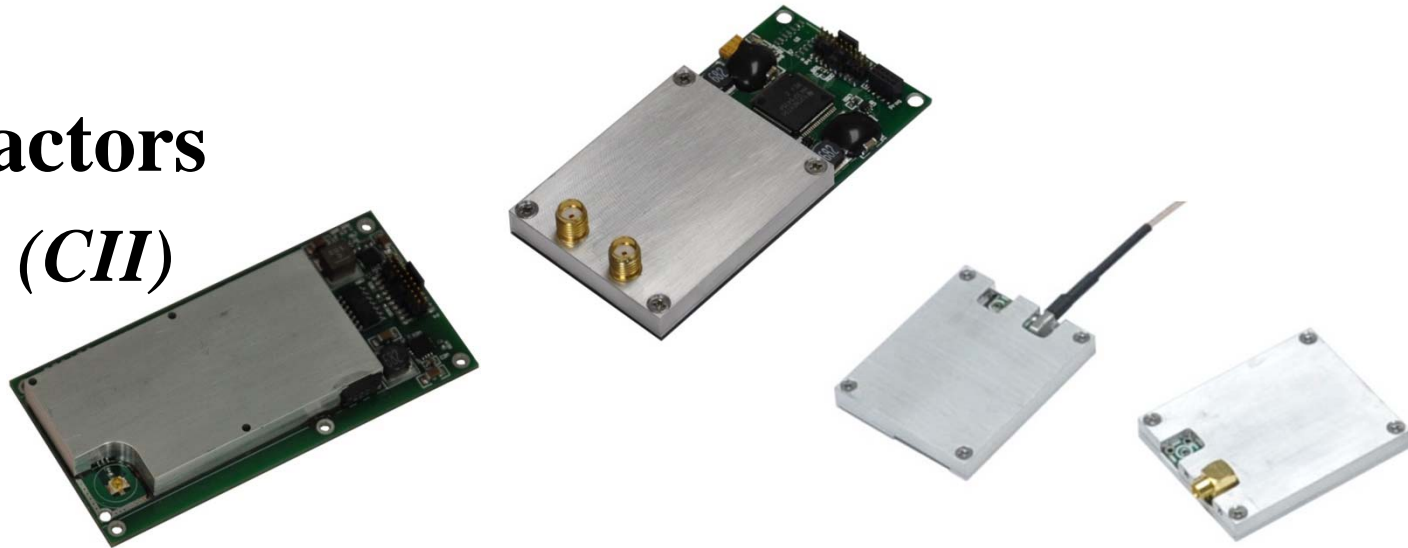
The Radio Bleeding Edge

The 2XX Radio Series

- *STM32 Processor*
  - *>100 MHz ARM*
  - *AES 256, 115 kbps continuous*
  - *1 Mbit Flash = Redundancy*
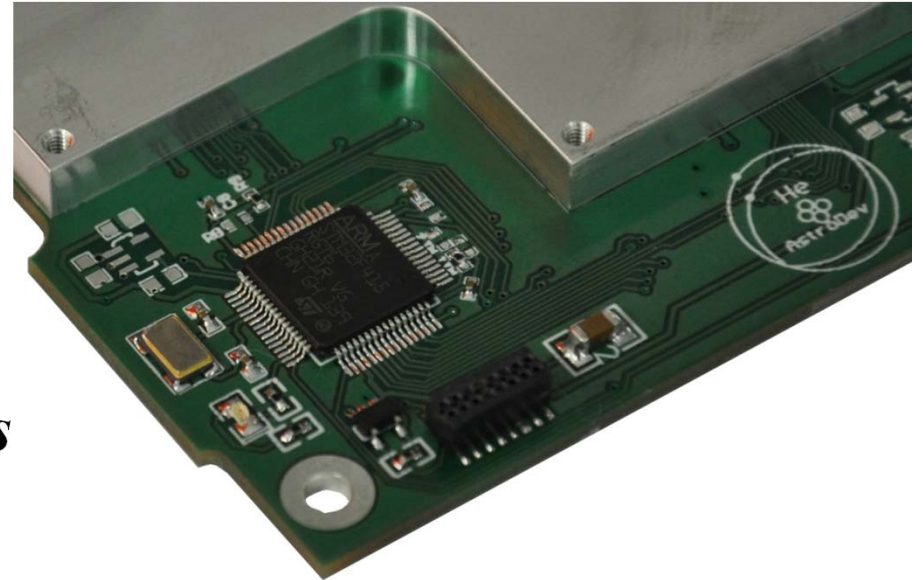
Form Factors

- *Colony (CII)*
- *Li-1B*

The Radio Business

Quantity of missions has expanded greatly.

- Keeping low cost has been challenging
- Customization increases support
- Support increases cost
- Cost causes single unit orders
- Single units = No growth?

Costs have continued to
climb, greatest cost: **Software**

Radios Annual Production