Technology Development of a Compact Radar Digital Receiver

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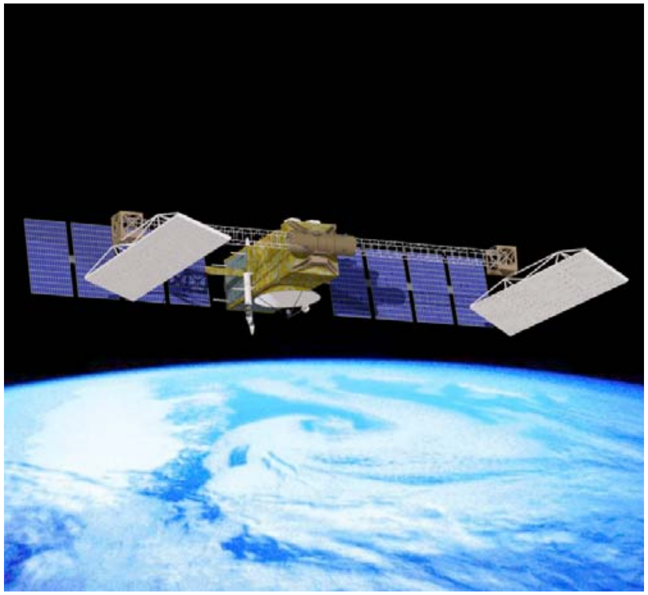
Background / System Concept

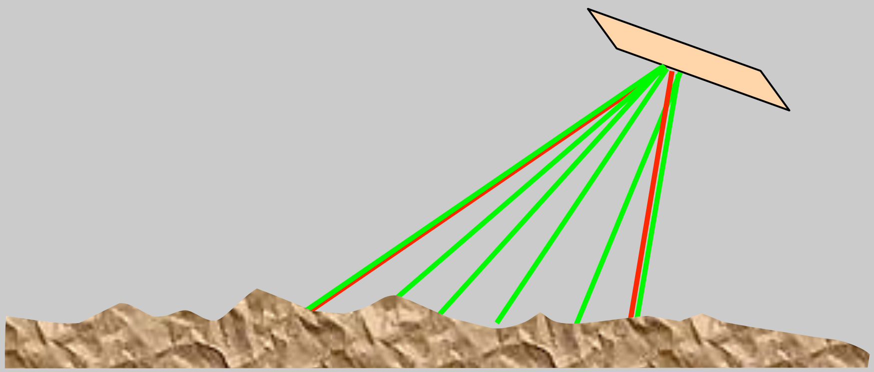
Background – IIP System Overview

Ka-Band (35GHz) single-pass interferometric synthetic aperture radar (InSAR) operating with a 70km swath:

- insensitive to cloud cover
- mm-wavelength minimizes snow penetration
- mm-wave frequency yields high accuracy with small baseline

Digital-beamforming elevation array on receive maintains high gain at achievable transmit powers. Approximate 12-fold saving in transmit power for same swath-width with conventional SAR.

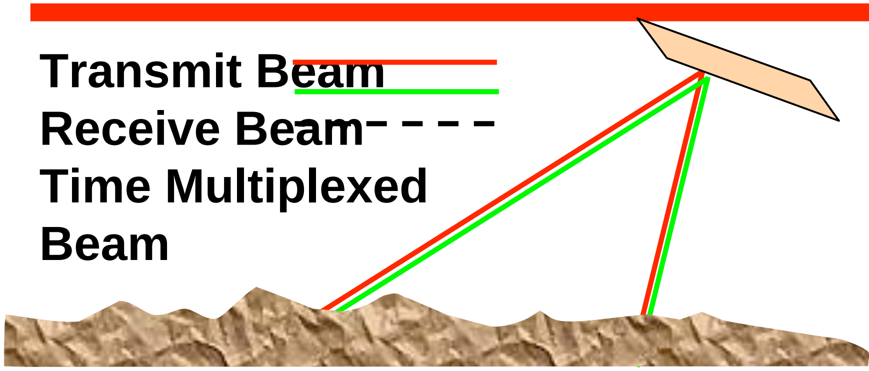




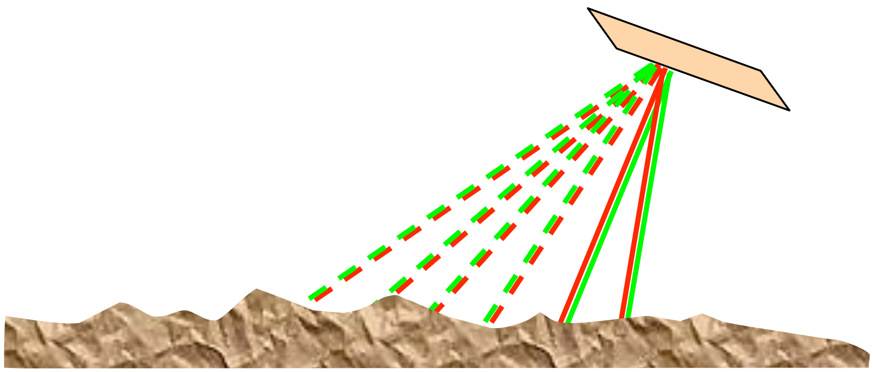
Digital Beamforming in Elevation:
- Wide beam on transmit to illuminate entire area
- Large antenna synthesized on receive to form beams in all possible positions *simultaneously* to both:
  - Improve gain when compared to Standard SAR
  - Improve number of independent samples when compared to ScanSAR
- Reduced transmit loss, ability to use tube transmitter
- Penalty is increased data rate and processing required

Digital Beamforming (DBF) Concept

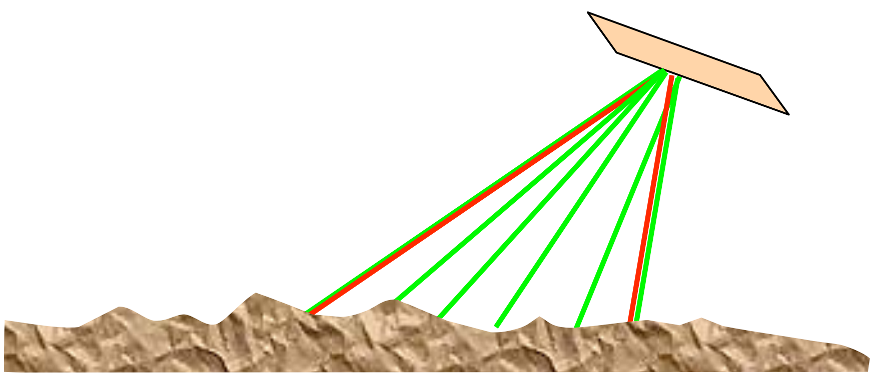
Transmit Beam
Receive Beam
Time Multiplexed Beam



Standard SAR:
- Wide beam in elevation to achieve significant swath
- Penalty of lowest gain
- No timesharing, so number of independent samples is maximized



Scan SAR:
- Narrow elevation beam used to increase gain
- Swath achieved by electrical scanning and time multiplexing "subswaths", reducing number of independent samples per subswath
- Phase shifter losses favor use use of active array (complex, immature and expensive at Ka-band) instead of simpler, more economical tube transmitter



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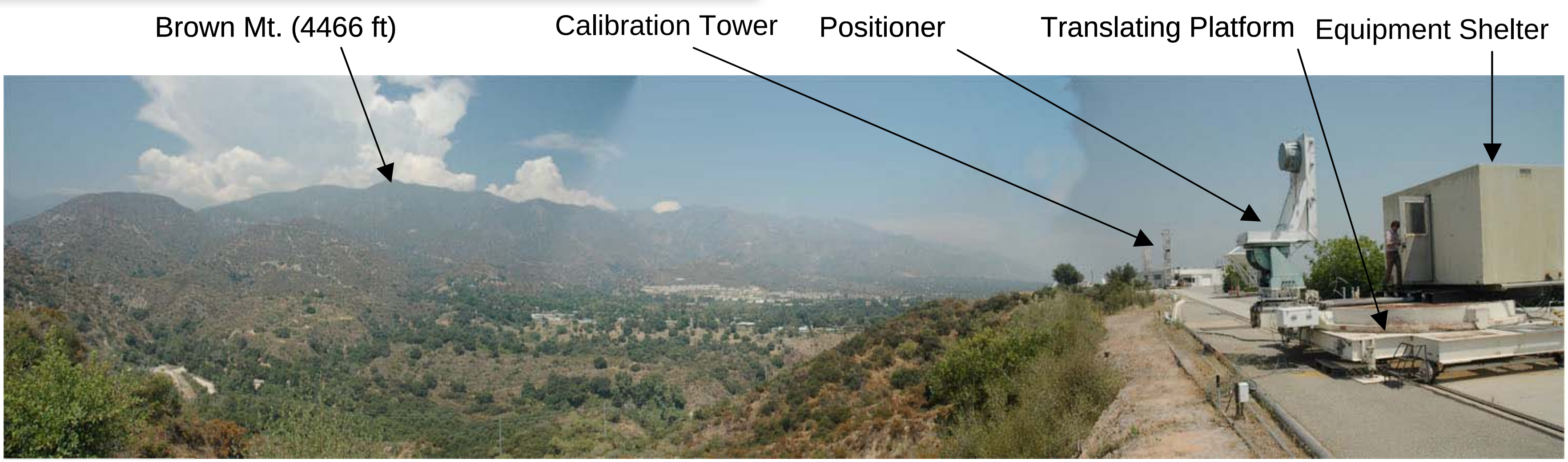
Demo Objective

To characterize and demonstrate the calibration and performance of the antenna array and the end-to-end concept of the DBF interferometric image synthesis.

- DBF used to scan in elevation on a fine-scale coupled with elevation scanning on a coarse-scale using the positioner
- A 0.5m interferometric baseline is achieved by halving the effective aperture

Demo Site: JPL Antenna Range

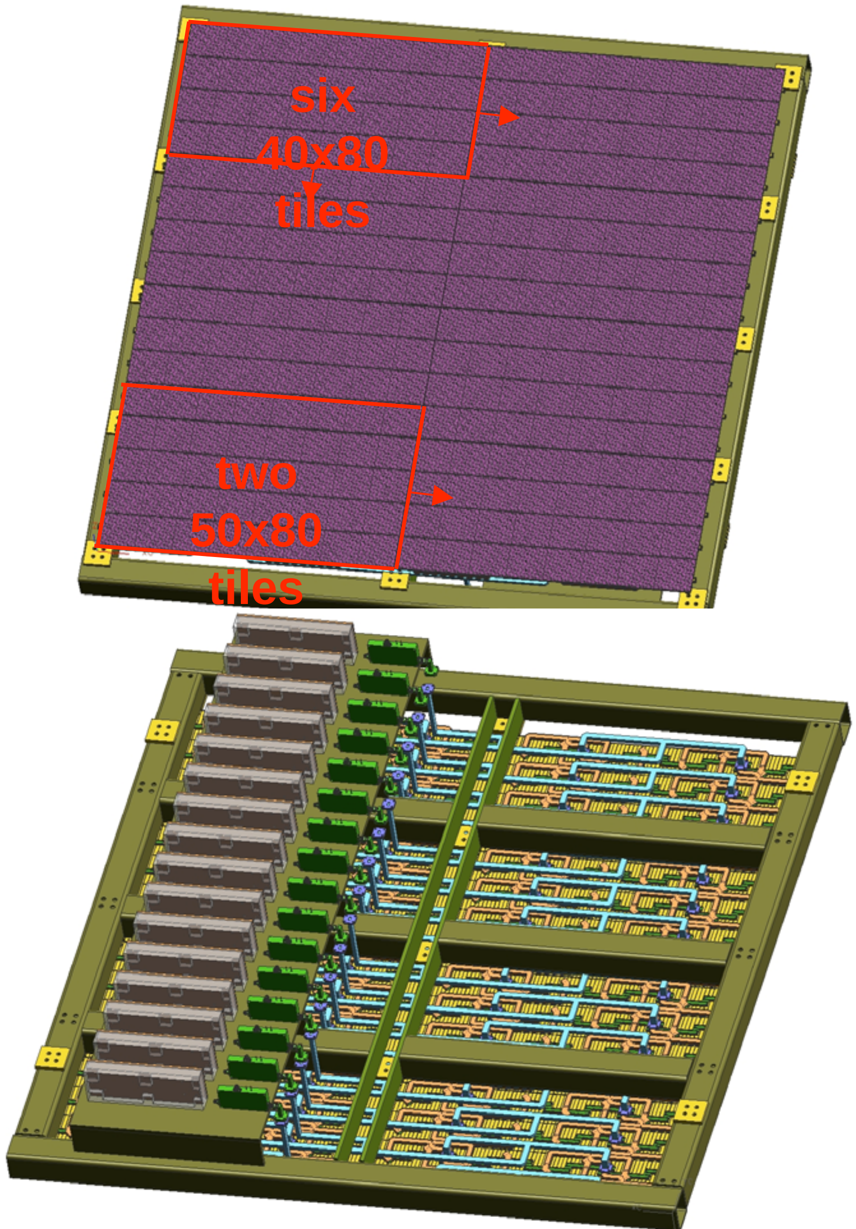
- Situated on ridge top with north (mountain) and south (laboratory) views
- Can also view calibration source on tower
- Positioner system translates, rotates in elevation and azimuth
- Climate controlled shelter for equipment and operator



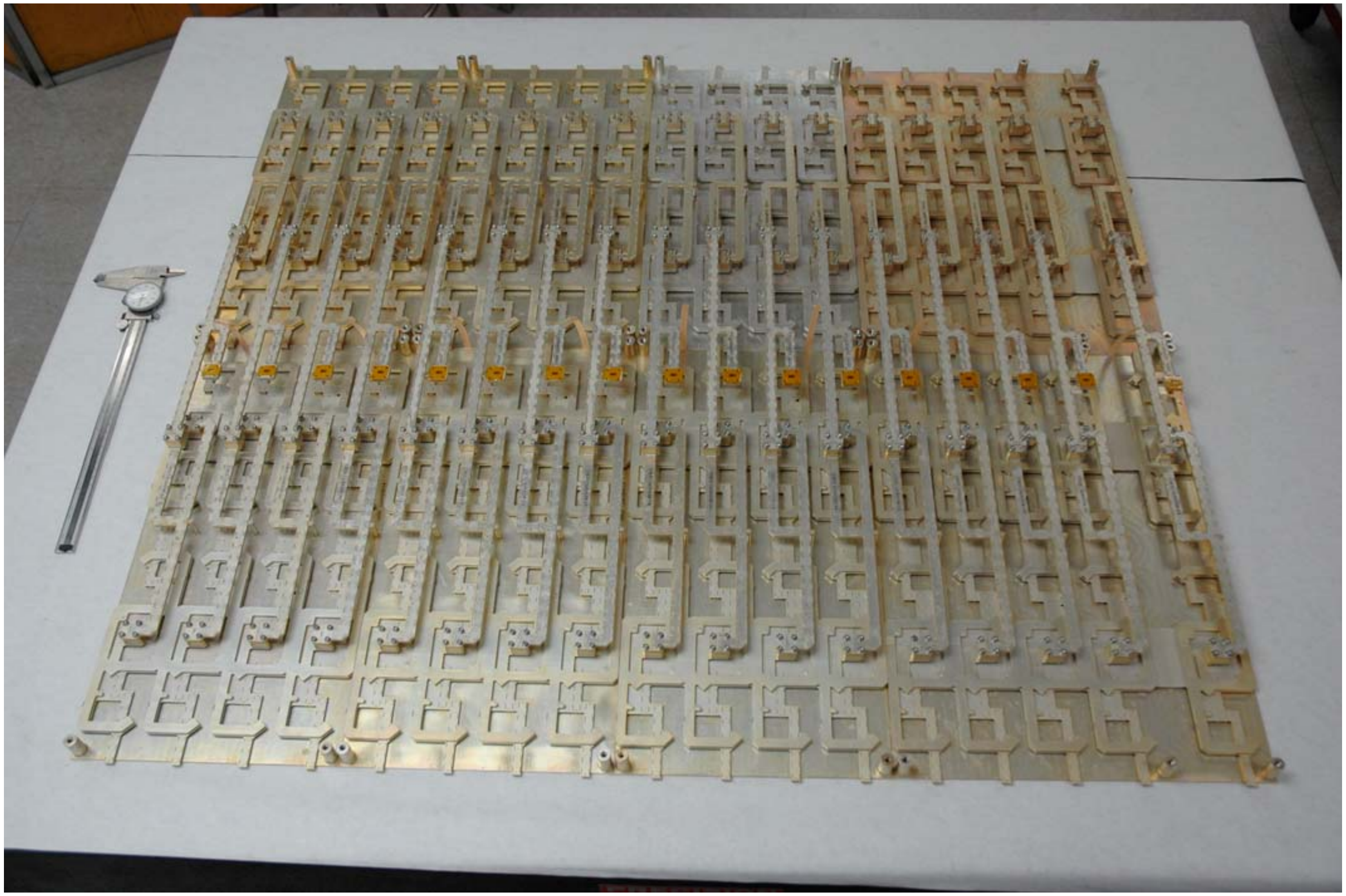
Elevation Array Development

Main features of demonstration array

- Demonstration size is 1.1m x1m or 1/4 the size of the spaceborne design (ie one "panel" in the nominal configuration)
  - Electrically, the individual slotted waveguide antennas are 10x160 slots, but are mechanically configured as six 40x80 and two 50x80 slot array tiles
  - fifty-one WR28 3dB dividers combine the slotted waveguides in the H-plane to form one transmit and sixteen receive "sticks".
  - 102, WR28 shims for phase trimming as necessary
  - support frame for tile alignment and electronics housing
- Receiver electronics mounted directly and compactly on rear of antenna



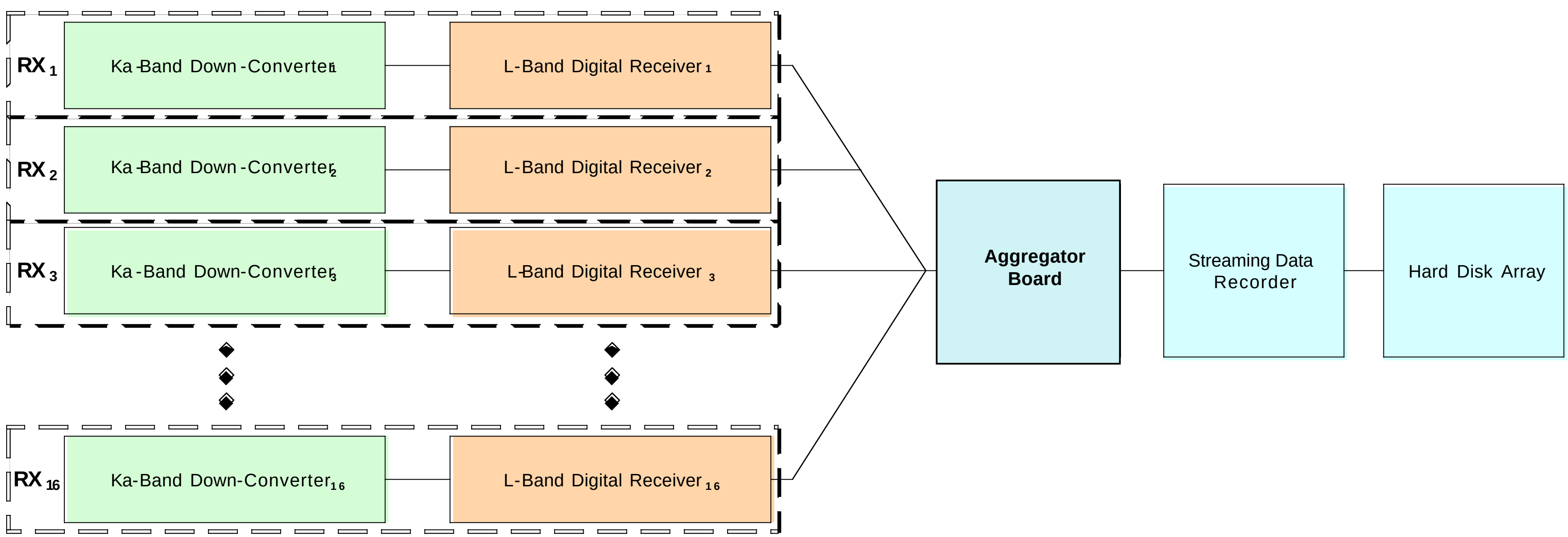
Demonstration Antenna Array



Receivers

Receiver Block Diagram - Overview

- One receiver per antenna element
  - Ka-band down-converter
  - L-band digitizer
- 16 receiver outputs multiplexed into single high-speed data stream
- Data stored on large hard-disk array for post-processing



Receiver Overview

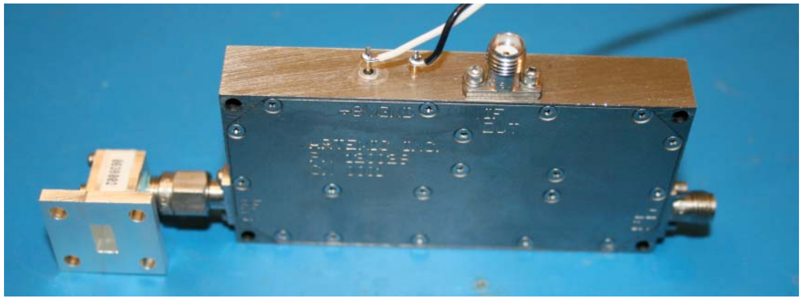
- Down-converter
  - Ka- to L-band
- Digital Receiver
  - Requirements
    - Directly sample L-band input
    - Compact, mount directly to antenna
    - Multi-channel capable
    - Path to spaceborne implementation
  - No COTS hardware available
  - Goals in custom development
    - Meet mechanical & electrical requirements requirements
    - Design in flexible manner so that can be utilized in many applications

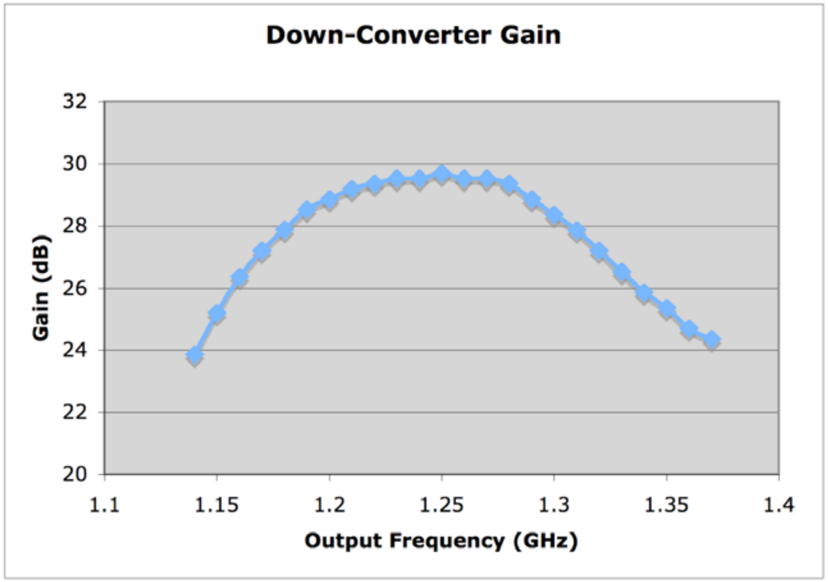
Parameter	Requirement	
	Flight	**Demo**
Bandwidth	40 MHz	80 MHz
Receive Window	178 usec	50 usec
PRF	4 kHz	500 Hz
Noise Figure	4.5 dB	4.5 dB
Effective # of Bits	> 7 bits	> 7 bits
ADC Jitter	< 0.01 nsec	< 0.01 nsec
Receive Filter Ripple Amplitude Deviation	< 0.3 dB	< 0.3 dB
Receive Filter Phase Ripple RMS Error	< 2 deg	< 2 deg

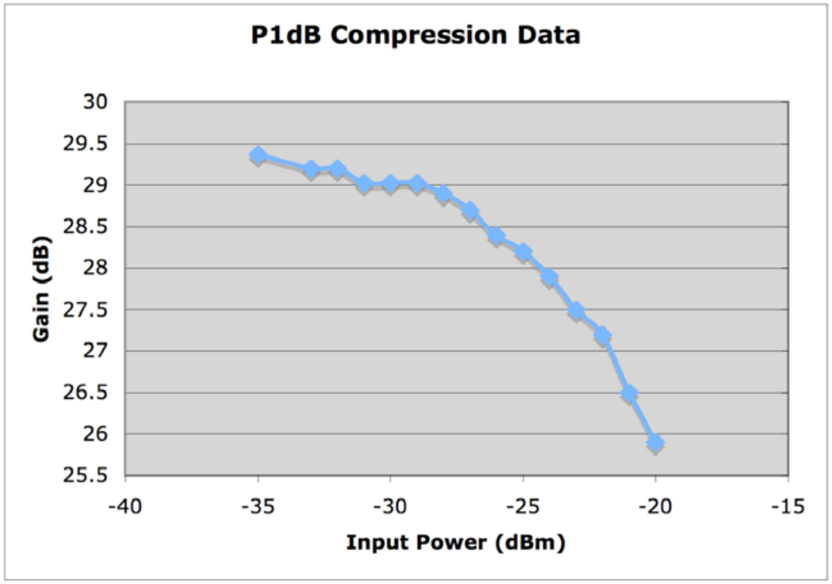
*Differences in flight & demo requirements due to different timing solutions for the measurement scenarios

Down-Converter

- Ka-band down-converter element
  - Down-converts input Ka-band signal to L-band
  - Utilizes image-rejection, even-harmonic mixer
  - Procured as a single, connectorized component

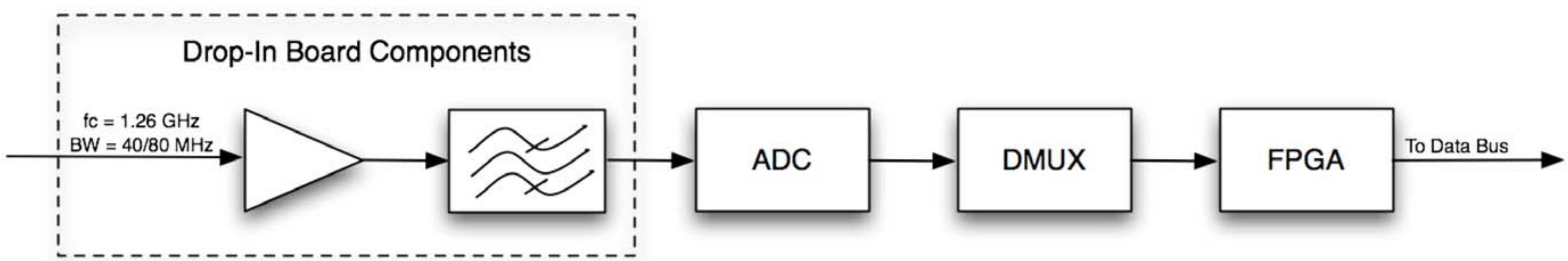






Digital Receiver – Analog Overview

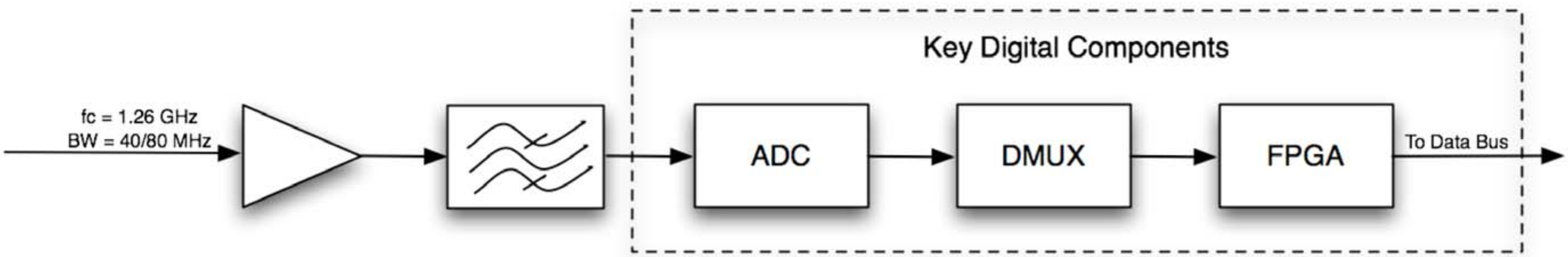
- L-Band digital receive element
  - Analog front-end consists of simple "drop-in" board
  - Drop-in board sets receiver parameters
    - Center frequency
    - Bandwidth
    - Signal level
  - Front-end provides flexibility for use in alternate applications
- Front-end components
  - Amplifier
  - BPF



Digital Receiver - Digital Overview

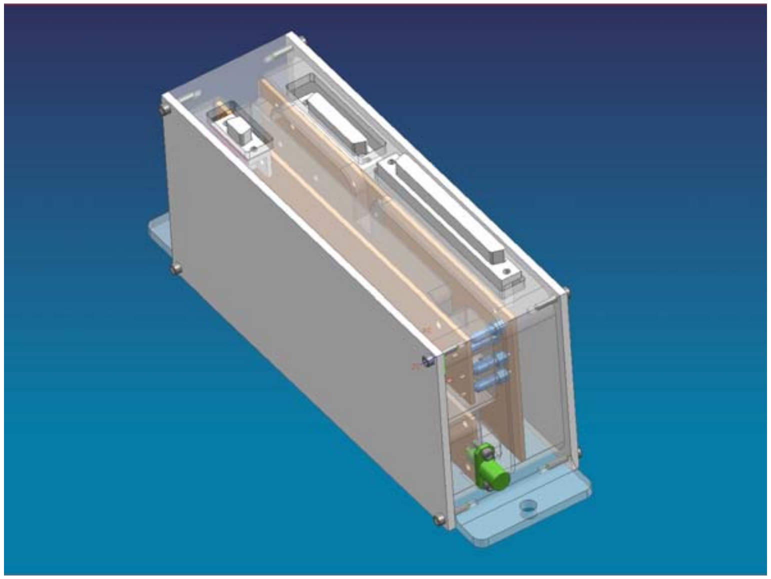
- L-Band digital receive element
  - Bandpass sampling of L-band signal (output of front-end)
  - Onboard FPGA controls data bus interface and enables real-time processing capabilities
  - Key components available in radiation-hardened equivalents

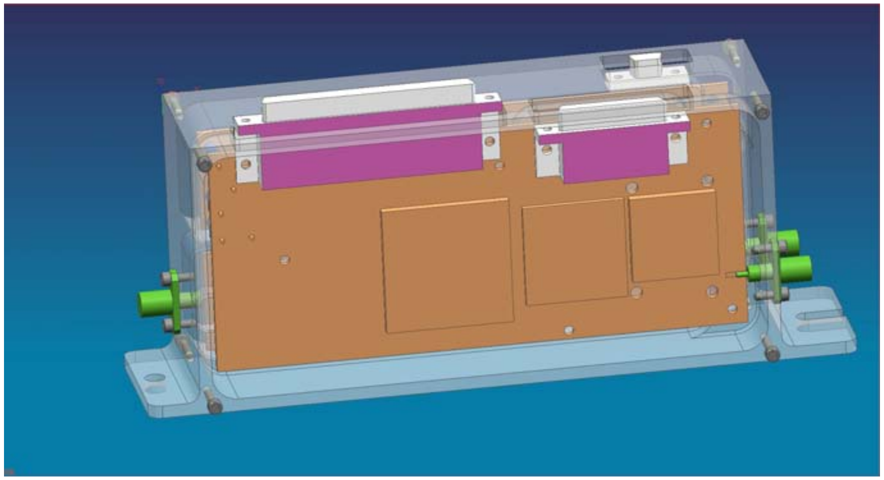
- Key digital components
  - A/D
    - Sample rate up to 2.2GS/s
    - Input up to 3.5GHz
    - 10 Bits
  - DMUX
    - 1:2 or 1:4
  - FPGA
    - Serves as FIFO
    - Controller for bus interface
    - Oversized

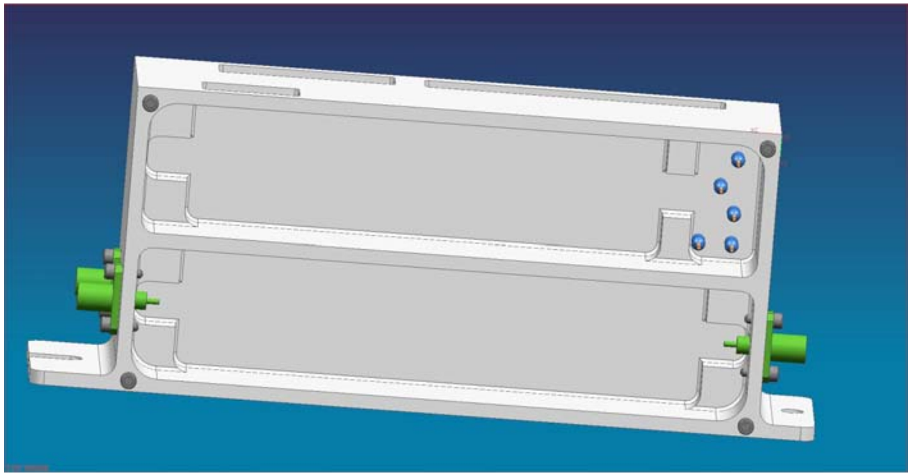


Digital Receiver - Housing

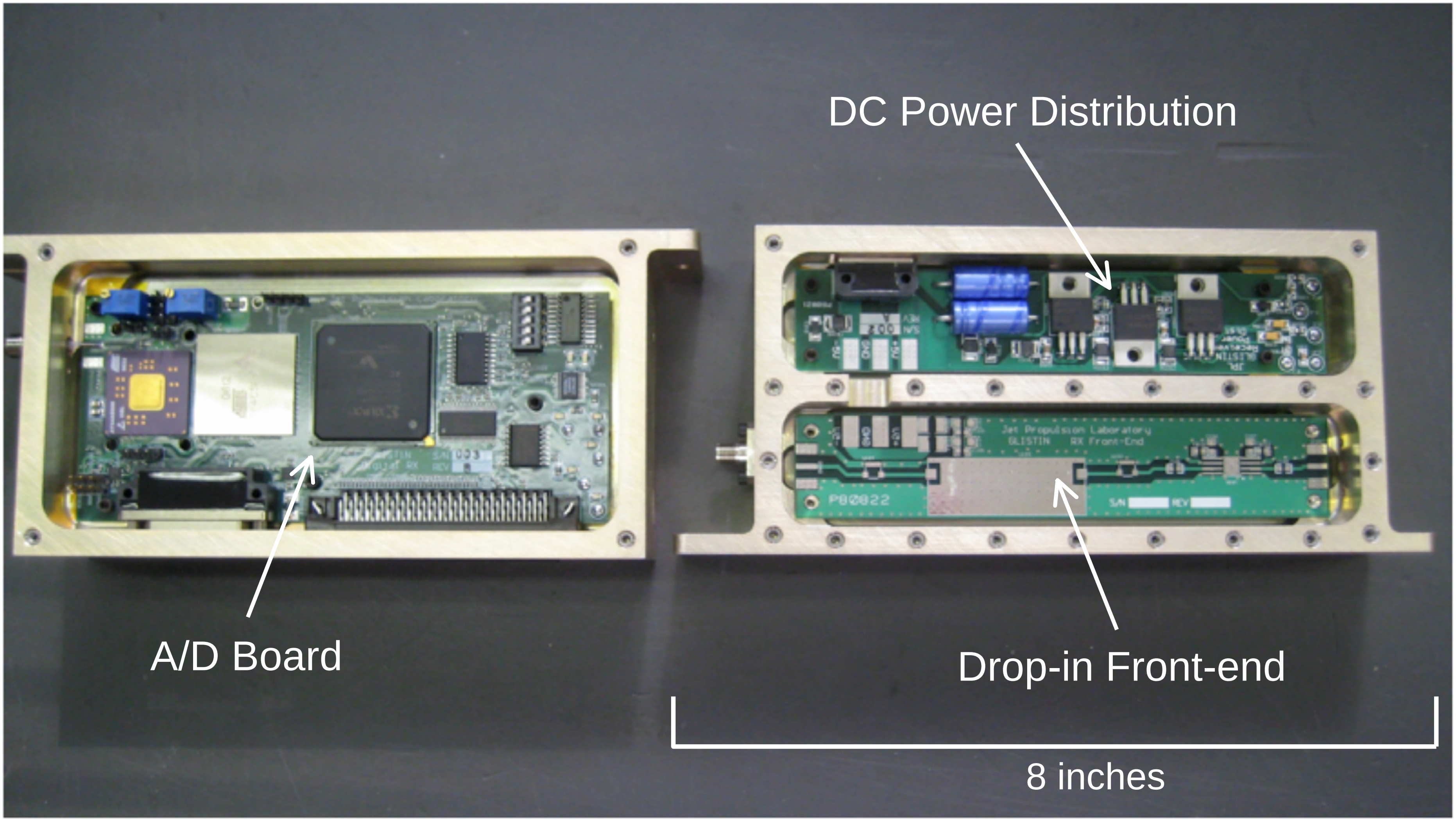
- Double-sided housing
  - Digital A/D board
  - RF front-end board
  - DC power distribution board
- Housing provides RF / digital isolation and serves as heat sink





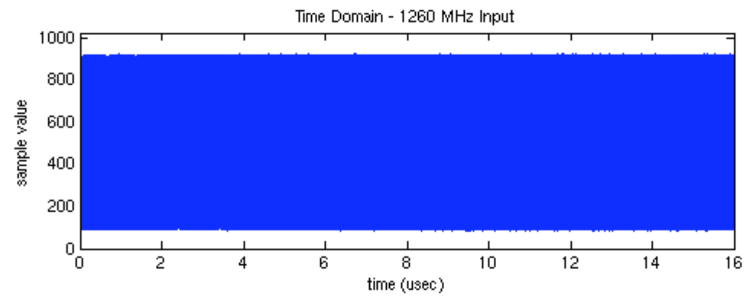


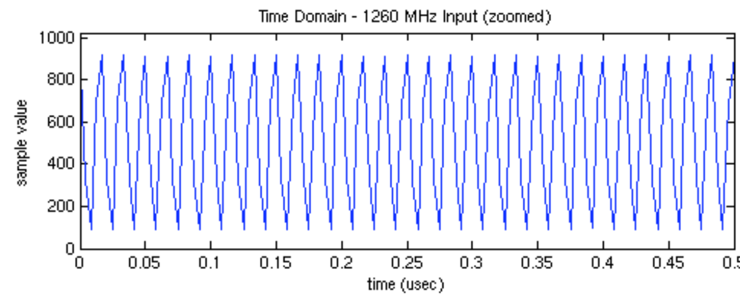
Demo Digital Receiver

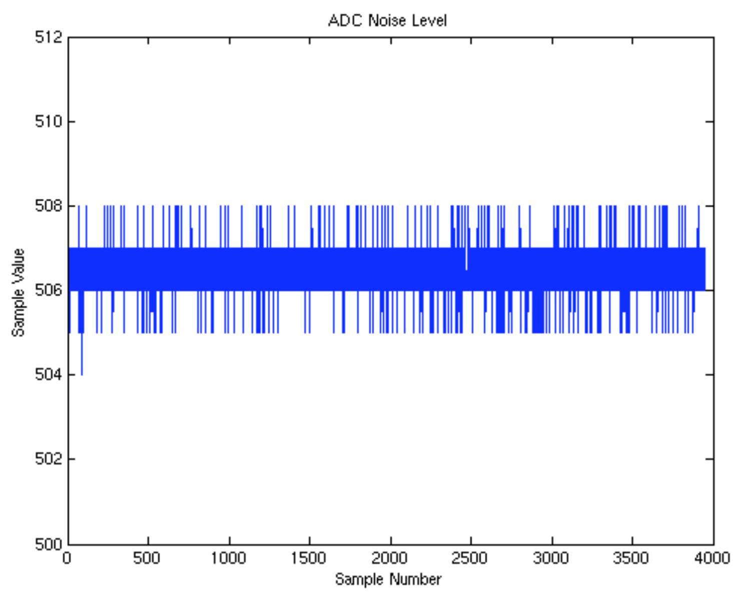


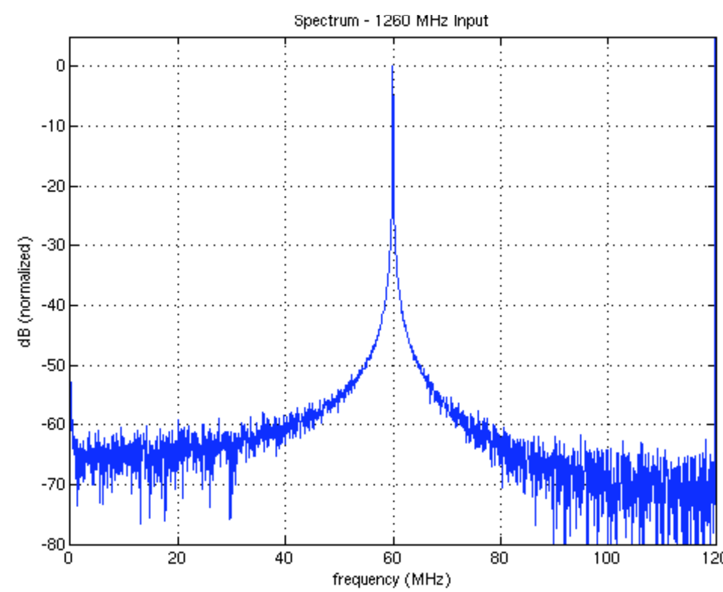
Receiver Data

- Prototype Digital Receiver
  - Data collected on logic analyzer
  - 1260 MHz input from synthesizer
  - On-board FPGA used as data buffer ar FPDP controller







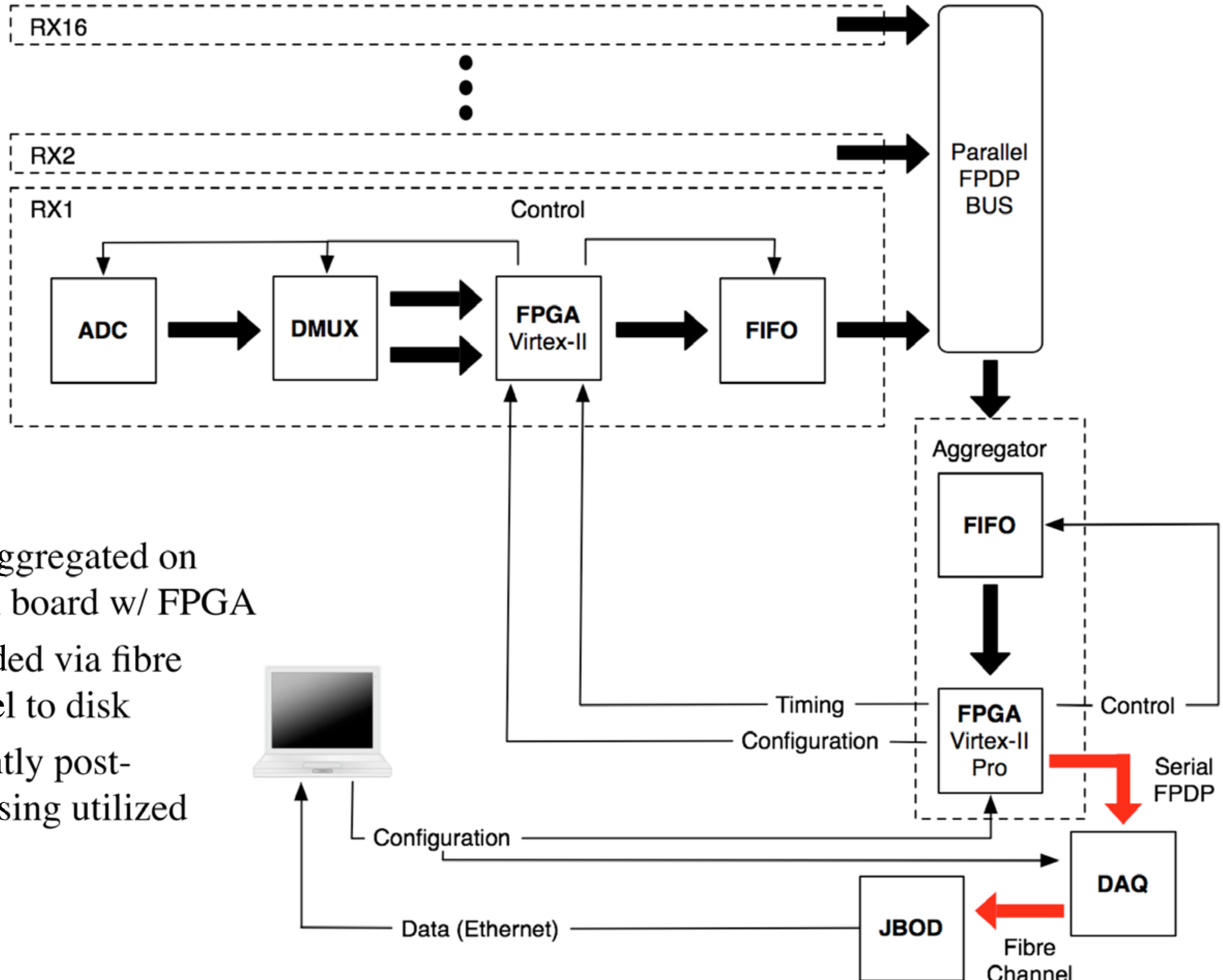


Multi-Channel Configuration

Multi-Channel

- Demo Instrument
  - 16 Rx elements
  - 1m x 1m antenna array
- DBF Receiver Network
  - Receivers function in coordinated manner
  - FPDP
    - Supports 16 element multi-drop bus within 1 m
    - Up to 400 MB/s data rate supported on bus
    - Not suitable for flight config
  - Aggregator to disk
    - sFPDP

Multi-Channel Digital Design



- Data aggregated on central board w/ FPGA
- Recorded via fibre channel to disk
- Currently post-processing utilized

Versatility

- Single or multi-channel
- Center frequency / BW & signal level
- Sampling rates
- Compact
- DSP
- Path to flight readiness

Technology Development Status

- L-Band digital receivers
  - Prototype design verified and bench-tested
  - Presently in early stages of multi-channel testing
- Aggregation board
  - Simple speed tests performed over optical link
  - Presently in early stages of testing in conjunction with receivers

Questions?