



# ***Frontier Radio Lite: A Single-Board Software-Defined Radio for Demanding Small Satellite Missions***

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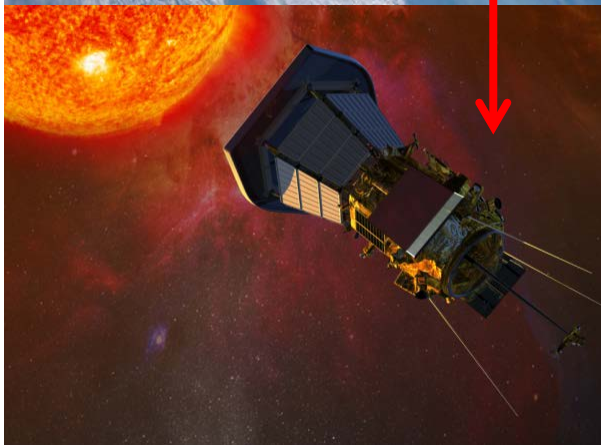
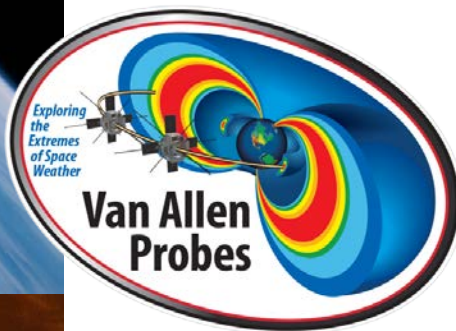
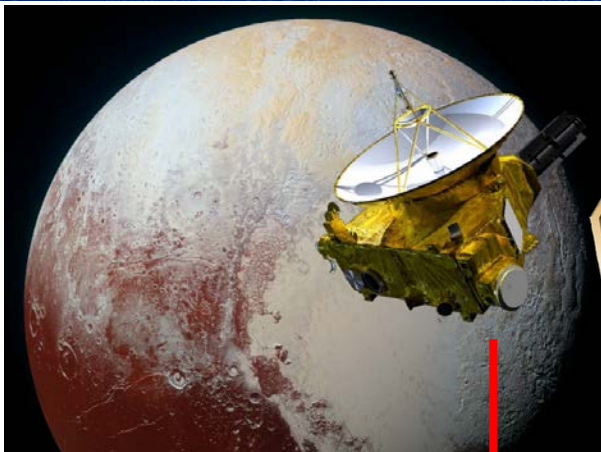
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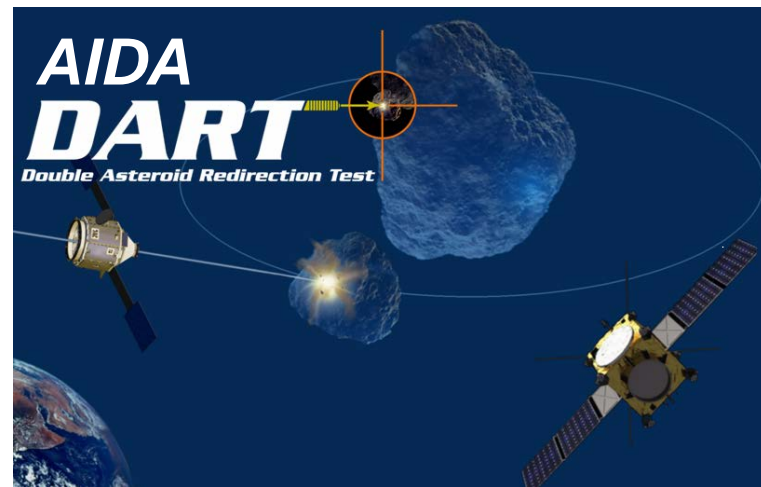
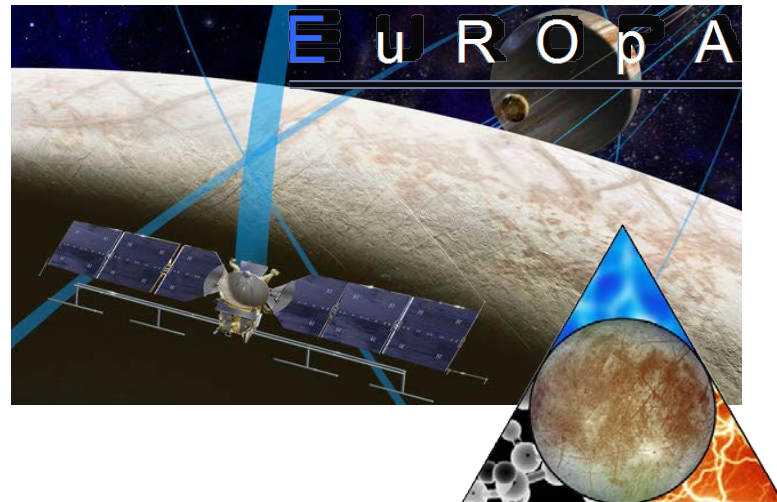


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# Frontier Radio Evolution



**Solar  
Probe  
Plus**





# Background & FR Lite Need

## ■ Frontier Radio

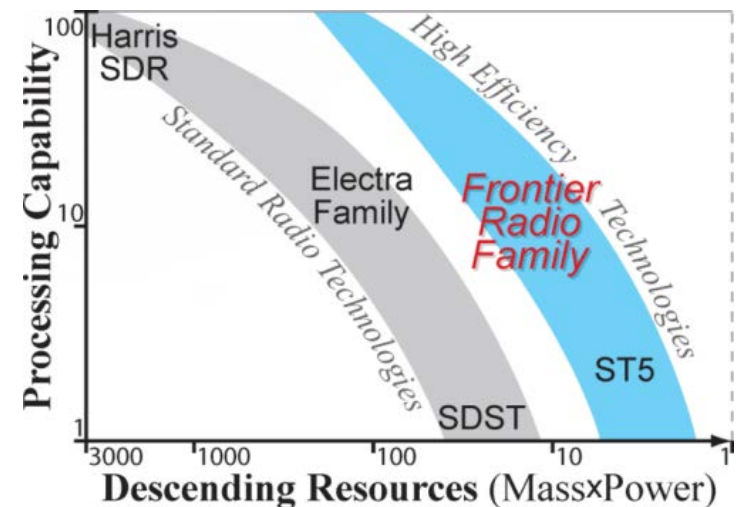
- TRL-9 SDR, evolved from New Horizons radio
- Low power, low mass, highly efficient, very high reliability
- Van Allen Probes (S-band), operational
- Solar Probe Plus (X/Ka-band) & Europa Clipper (X/Ka-band), to be flown
- TID radiation tolerance: >100 krad



Flight Solar Probe Plus Frontier Radio

## ■ Highly Resource-Constrained Missions

- Smaller budgets
- Require fit into cubesat form factors
- Require even lower power consumption
- Quick adaptation for new needs
- Cannot compromise reliability and performance



Frontier Radio & FR Lite Market Position

# The Frontier Radio Lite

- **Full Duplex SDR: 4+ slices in 1**

- Power Converter
- Digital Signal Processor
- Receiver
- Exciter
- Plus: 1-W Power Amplifier

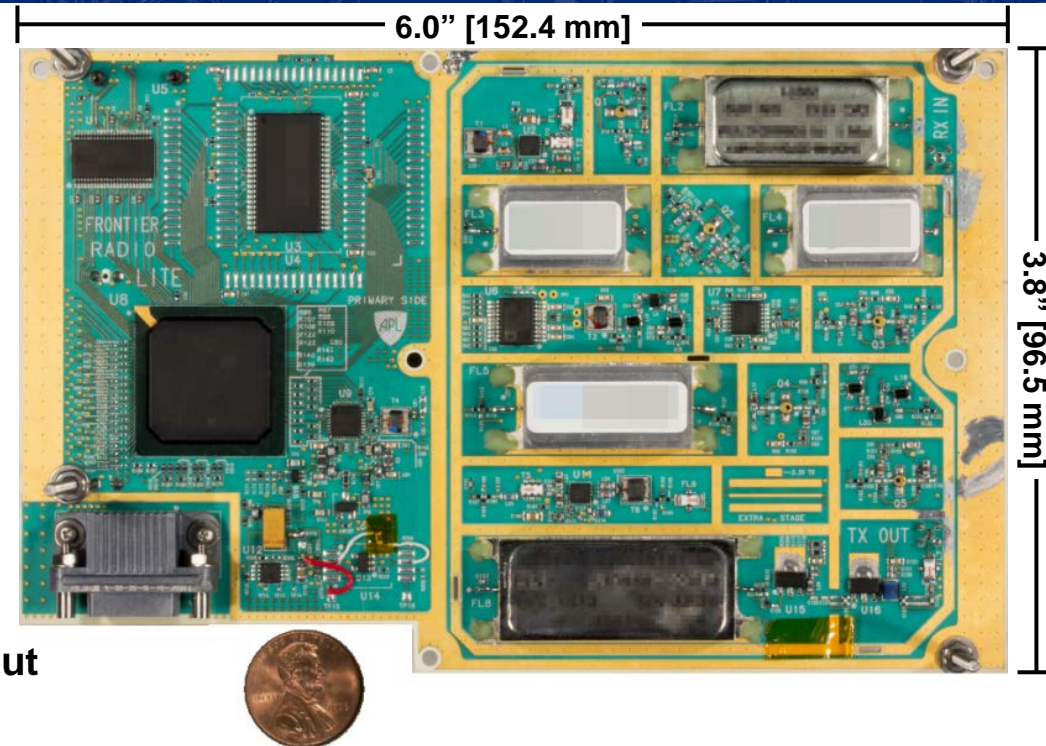
- **Extremely Low SWaP**

- Volume: 320 cc
  - Mass: 0.4 kg
  - Full Duplex Power: 4 W
  - Rx Power: 1.4 W
  - Standby Power: 0.35 W
- } 6-9 V Input

- **Extremely robust**

- Radiation TID Tolerance: 20 krad
- Radiation SEL Immunity:  $>68 \text{ MeV-cm}^2/\text{mg LET}$  (limited by FPGA)
- Long Mission Durations: *Decades* not Months

- **Reconfigurable for UHF, L, S, or C-band at manufacture**



# Comparison of S-Band Radios

Van Allen Probes Frontier Radio (left) vs. FR Lite (right)



## ■ Improvements

- <25% mass
- <20% volume
- <30% receive & full duplex power
- <7% standby power

*LargeSat Capability*  
*MicroSat SWaP*

## ■ Retains nearly all capabilities, e.g.

- Two-way coherency for Doppler navigation
- Autonomous fault protection functions
- Proven robust parts (high radiation tolerance, long mission durations)

# Enablers

## ■ Actel RT ProASIC3 FPGA

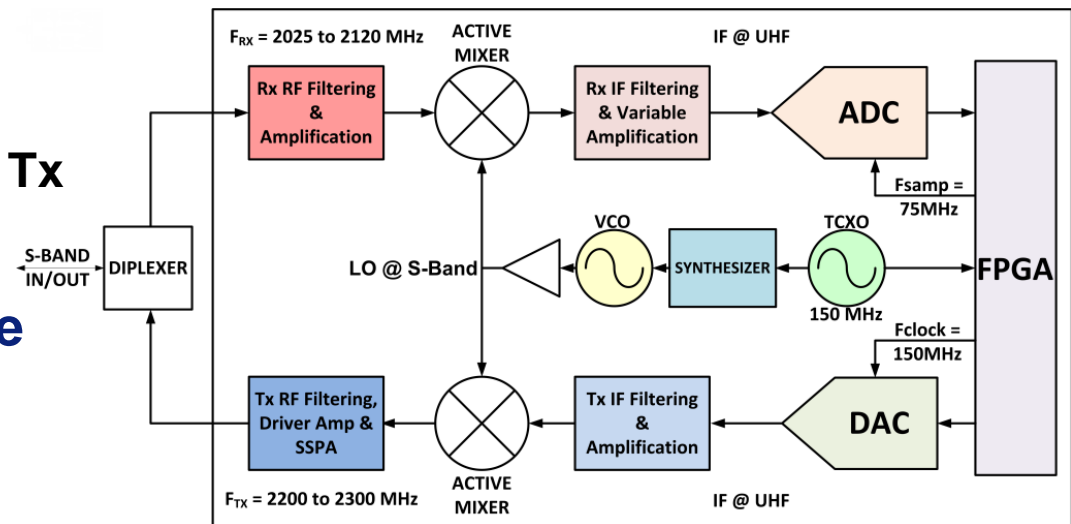
- Lower cost, size, power consumption vs. Actel RTAX FPGA
- Reprogrammable!
- Gives up some radiation tolerance (TID, some SEL immunity)

## ■ Analog hardware to digital firmware

- High speed ADC & DAC → allow IFs in 100's of MHz instead of 1's to 10's
- DDS in the FPGA
- Modulation at IF in FPGA
- Single LO chain for Rx and Tx

## ■ Attention to self interference

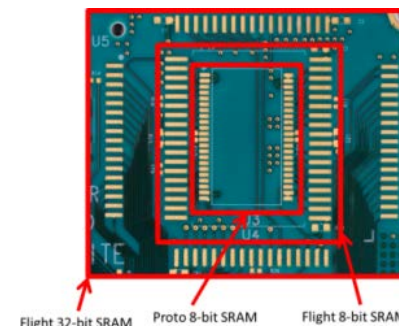
- Extensive RF shielding
- Split grounds
- Signal trace modeling in HyperLynx





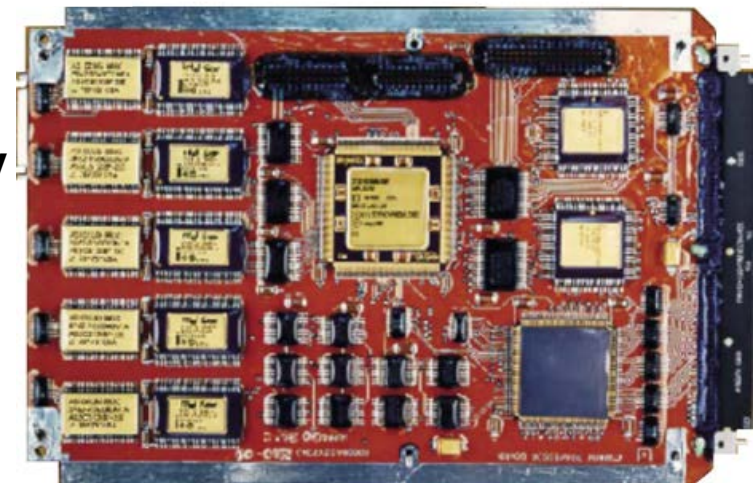
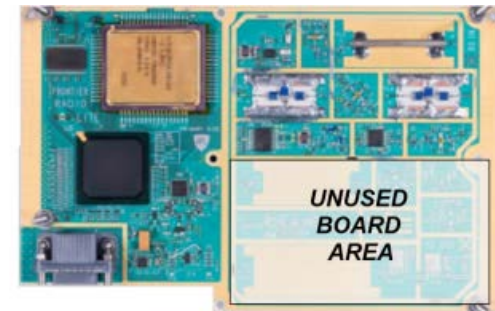
# Agile & Adaptable Design

- **Target any RF frequencies UHF through C band**
  - Mostly passive component changes
  - Retune amplifiers, replace filters
- **Multi-Footprinting**
- **Cost Flexible**
  - Populate with parts levels – commercial, upscreened, etc.
    - NASA levels 1, 2, or 3
- **Modular blocks (HW, FW, SW)**
  - Maintain mission agnostic libraries
  - Implement new schemes with minor changes to proven blocks
- **Vast array of communication schemes available**



# EGNS – A Rapid Adaptation Example

- **Need: Global Navigation Systems receiver (L1 & L2 bands)**
  - **Similar capabilities to APL-built NASA TIMED mission (2001)**
- **Used existing S-band transceiver PCB**
- **Passive component changes (retuned amplifiers, filters)**
- **New RF and IF frequencies**
- **Design time < 2 weeks**
- **Prototype assembly time < 2 weeks**
- **Compared to the TIMED processor board:**
  - **60% size reduction**
  - **Includes RF downconversion chain**
  - **Includes GPS Tracking ASIC functionality**
  - **Exceeds capabilities:**



Parameter	TIMED	EGNS
Pulse/Second Accuracy	85 ns	20 ns
Warm-Start Time	1-2 min	1 min
Cold-Start Time	12 min	1 min
Second GPS Frequency (L2C)	No	Yes
Combined GPS/OD Option	No	Yes



# Summary & Future Work

- **Significant improvements in size, weight, and power**
- **Agile, modular, reconfigurable design**
- **Extends Frontier Radio product reach**
- **Preserves high-reliability parts selection and core HW design**
- **Plan for a family of three FR products:**
  - **Full-fledged Frontier Radio (highest data rates, rad tolerance)**
  - **Frontier Radio Lite (quick, budget-constrained missions)**
  - **(In Development) Integrated Frontier Radio + Spacecraft Electronics**
    - **Two cards in same form factor as FR Lite**
    - **Single-board computer replaces processor boards for**
      - **Radio**
      - **Avionics**
      - **Processor Intensive Applications (e.g. image, radar, etc.)**
    - **Analog RF front end card provides access to UHF through X band**
    - **Multi-channel receive (e.g. S-band transceiver + GPS receiver)**
    - **Planned for DART mission**



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