Picture this SELFI:

Submillimeter Enceladus Life Fundamentals Instrument

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Presentation Outline & SELFI Project Team

Outline

- What is SELFI
- Team Organization
- SELFI Science Objectives
- SELFI Technical Objectives
- RF System Architecture & Design Approach
- Accomplishments to date

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Science Team:
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Terry Hurford/698
Tim Livengood/693/UMD
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Systems Engineer: Paul Racette/555

Spectrometer Front End
PDL – Negar Ehsan/555
Jared Lucey/555
Kevin Horgan/555

Back End Electronics/Digital Spectrometer
PDL – Damon Bradley/564
Tracee Jameson/564
Igor Kleyner/564
Rich Katz/564
Lynn Miles/564

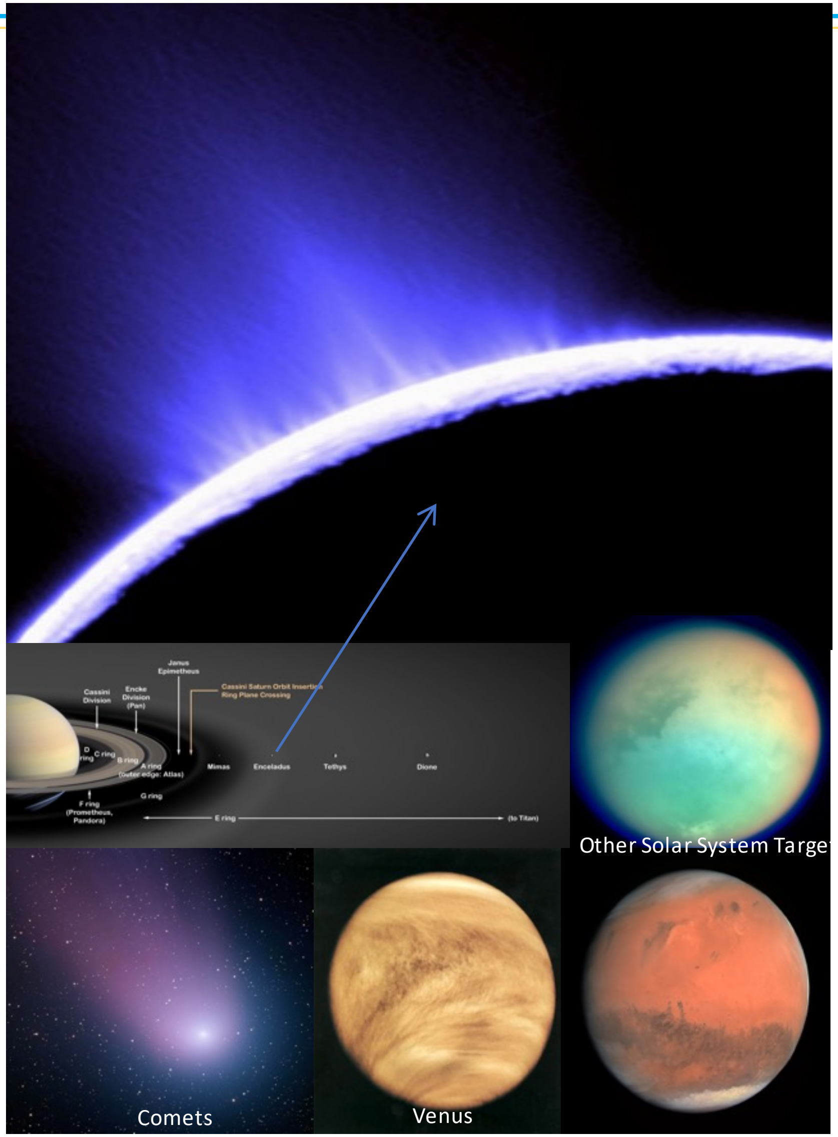
Integration and Test
PDL - Kevin Horgan

What is SELFI?

- SELFI is a 3-year project of the Maturation of Instruments for Solar System Exploration (MatISSE) program
- SELFI is NOT:
  - Spaceflight project/mission
  - Spaceflight instrument (yet)
- SELFI is a technology maturation project

Project Objective: Advance the readiness to make submillimeter spectroscopic measurements of volatile constituents of Enceladus' plumes

SELFI Science Objectives



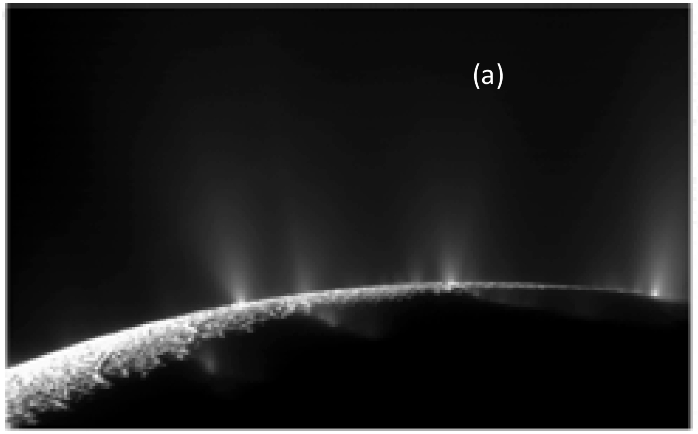
SELFI observes nearly simultaneously 14 molecular species that are important in the context of life and habitability (five of CHNOPS elements necessary for life) of the Enceladus' subsurface ocean.

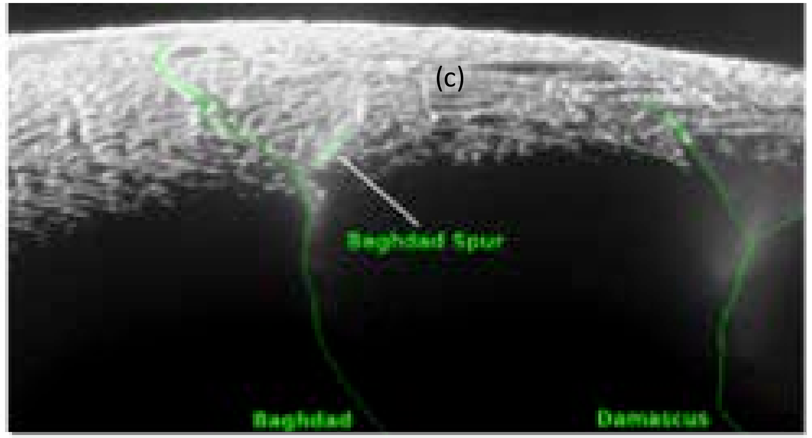
- Assess plume spatial/temporal compositional variability;
- **H_2O, HDO**, and **$\partial^{18}O$**, and **$\partial^{17}O$** evidence of ocean evolution;
- **H_2O_2,** and **O_3** oxidation state of the sub surface ocean;
- **CO, NH_3, CH_3OH, HCN and HNC** are biologically relevant species;
- **SO_2** and **H_2S** links to pre-biotic molecules and volcanoes;
- **NaCl** provides salinity level of the subsurface ocean and the source of salt in the Saturn ring system.

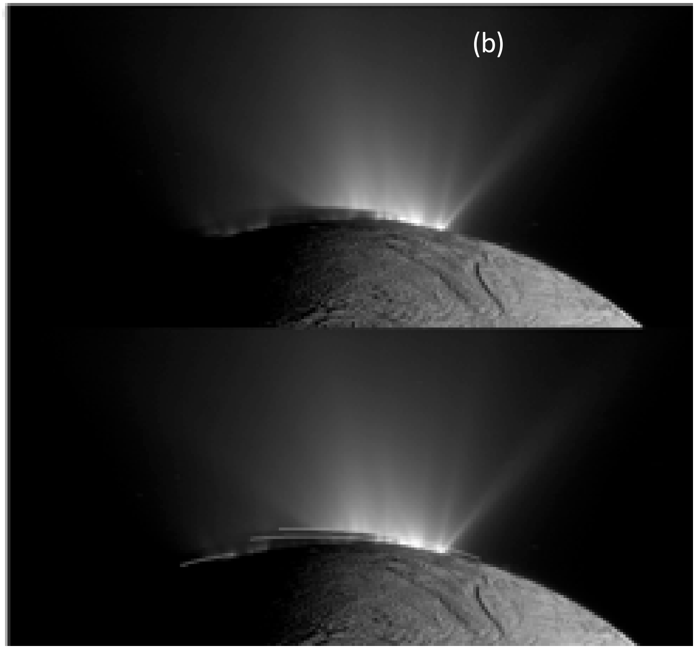
Continuum observations measure surface temperature from 30 - 250 K with 0.1 K resolution.

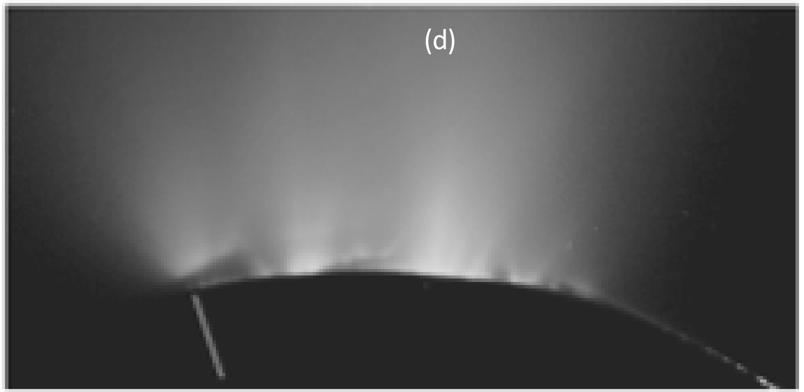
- Correlation of plume activity with surface temperature.

Enceladus Plume Observations









Enceladus' plumes are spatially (a) and temporally (b) variable, arising from fractures called Tiger Stripes (c), and may be curtains of eruptions whose density inhomogeniety gives an observational appearance of individual plumes (d).

From Porco, DeNino, and Nimmo Astronomical Journal 248, No. 3, 2014.

SELFI Target Molecules

Assume factor of 2 better than MIRO sensitivity to H_2O (161), 1×10^{12} cm^{-2} instead of 2×10^{12} cm^{-2} in 120 sec at ~296K
Display relative values of molecular species times water column of 1×10^{16} cm^{-2} assumed for Enceladus plume (from $(1–3)\times10^{16}$ cm^{-2}).
Cometary abundance: assume Despois *et al.* 2006; D/H ~3×10^{-4} from Bockelée-Morvan *et al.* 2004; others assume VSMOW.
Cassini INMS abundances: assume Hansen *et al.* 2006 water abundance, scaled to 0.96 from Waite *et al.* 2017; D/H ratio from Waite *et al.* 2009; others from Waite *et al.* 2008, Waite *et al.* 2017.
Cassini UVIS abundances: Hansen *et al.* 2008
Cassini VIMS abundances: Newman *et al.* 2007

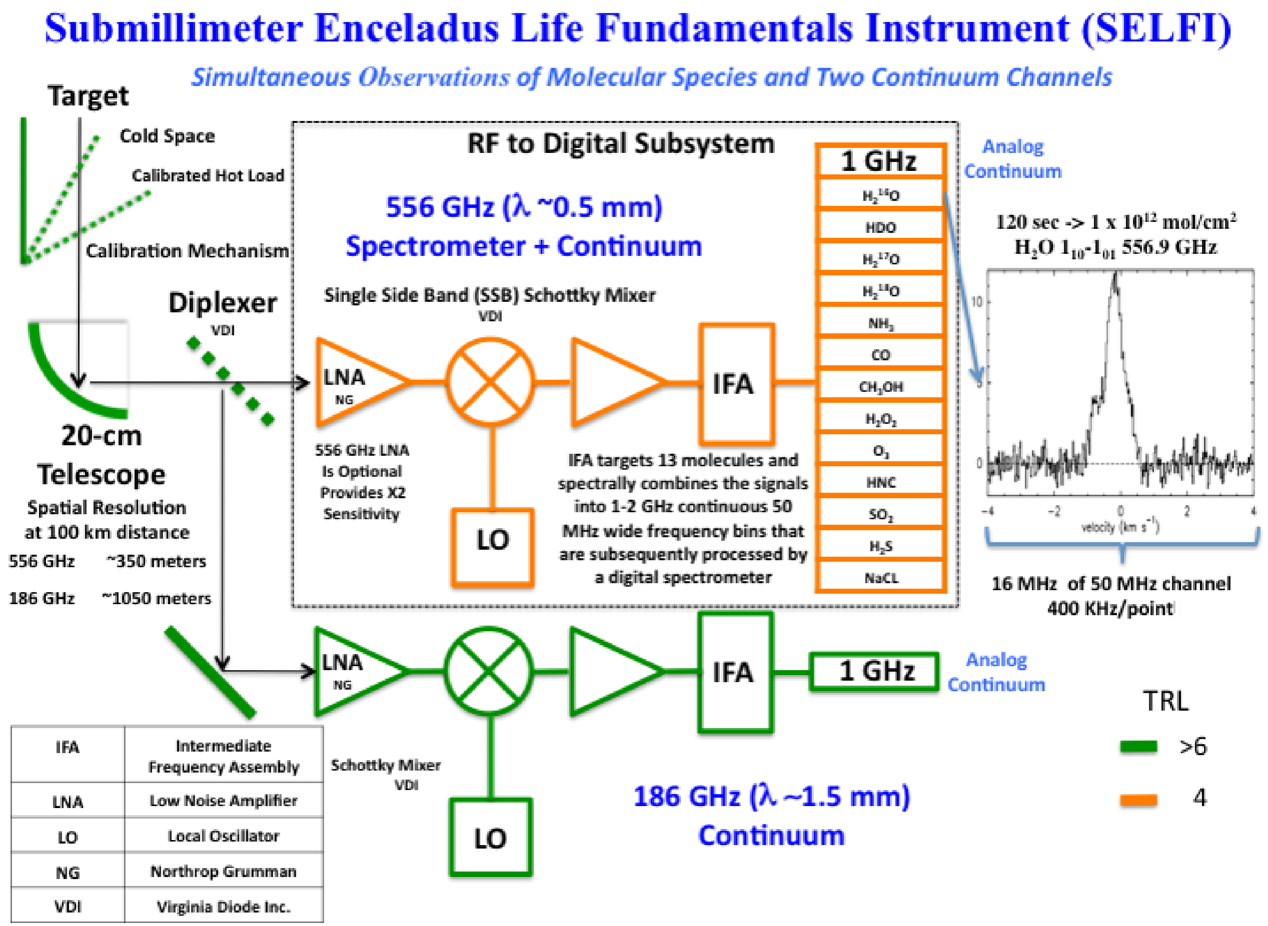
Detailed table of target species:

	Mol	Iso desig	Freq (GHz)	Proposed sensitivity @~120sec cm^{-2}	SELFI sensitivity @~120sec cm^{-2}, 296K	Cold Plume: SELFI sensitivity @~120sec cm^{-2}, 125K	Cold Plume: SELFI sensitivity @~120sec cm^{-2}, 91K	Cold Plume: SELFI sensitivity @~120sec cm^{-2}, 80K	Cassini abundances cm^{-2}	Cometary & VSMOW abundances
Isotopolog	H_2O	161	556.936	1×10^{12}	1×10^{12}	0.15×10^{12}	0.08×10^{12}	0.06×10^{12}	INMS: 1.44×10^{16} UVIS: $0.9\text{-}3\times10^{16}$	1×10^{16}
	HDO	162	599.927	1×10^{12}	1.8×10^{12}	0.30×10^{12}	0.17×10^{12}	0.14×10^{12}	INMS: 4.5×10^{12}	3×10^{12}
	$H_2{}^{17}O$	171	552.021	1×10^{12}	1.0×10^{12}	0.15×10^{12}	0.08×10^{12}	0.06×10^{12}		3.7×10^{12}
	$H_2{}^{18}O$	181	547.676	1×10^{12}	1.0×10^{12}	0.15×10^{12}	0.08×10^{12}	0.06×10^{12}		20×10^{12}
	NH_3	4111	572.498	1.4×10^{12}	4.9×10^{12}	0.61×10^{12}	0.29×10^{12}	0.21×10^{12}	INMS: 62.5-203×10^{12}	70×10^{12}
	CO	26	576.268	850×10^{12}	157×10^{12}	38×10^{12}	25×10^{12}	22×10^{12}	UVIS: $<360\times10^{12}$	2300×10^{12}
Isomer	HNC	142	543.897	7.2×10^{12}	0.27×10^{12}	*0.06×10^{12}*	*0.05×10^{12}*	*0.04×10^{12}*		4×10^{12}
	HCN	124	531.716	7.2×10^{12}	0.30×10^{12}	0.07×10^{12}	0.05×10^{12}	0.04×10^{12}	INMS: $<116\times10^{12}$	25×10^{12}
	CH_3-OH	2111-61	584.450	490×10^{12}	101×10^{12}	14×10^{12}	7.1×10^{12}	5.5×10^{12}	INMS: 2.34×10^{12}	240×10^{12}
	H_2O_2	1661	599.727	0.1×10^{12}	13×10^{12}	2.1×10^{12}	1.3×10^{12}	1.1×10^{12}	VIMS: $<75\times10^{12}$	$<3\times10^{12}$
	O_3	666	595.082	0.1×10^{12}	346×10^{12}	47×10^{12}	24×10^{12}	19×10^{12}		
	SO_2	626	593.945	10×10^{12}	43×10^{12}	6.4×10^{12}	3.6×10^{12}	2.9×10^{12}		20×10^{12}
	H_2S	121	568.050	7×10^{12}	49×10^{12}	11×10^{12}	8.2×10^{12}	7.5×10^{12}	INMS: 0.328×10^{12}	150×10^{12}
	NaCl	35	569.964	$\sim0.1\times10^{12}$	0.14×10^{12}					0.06×10^{12}

Expanded list of targeted species to include HNC

Technical Objectives

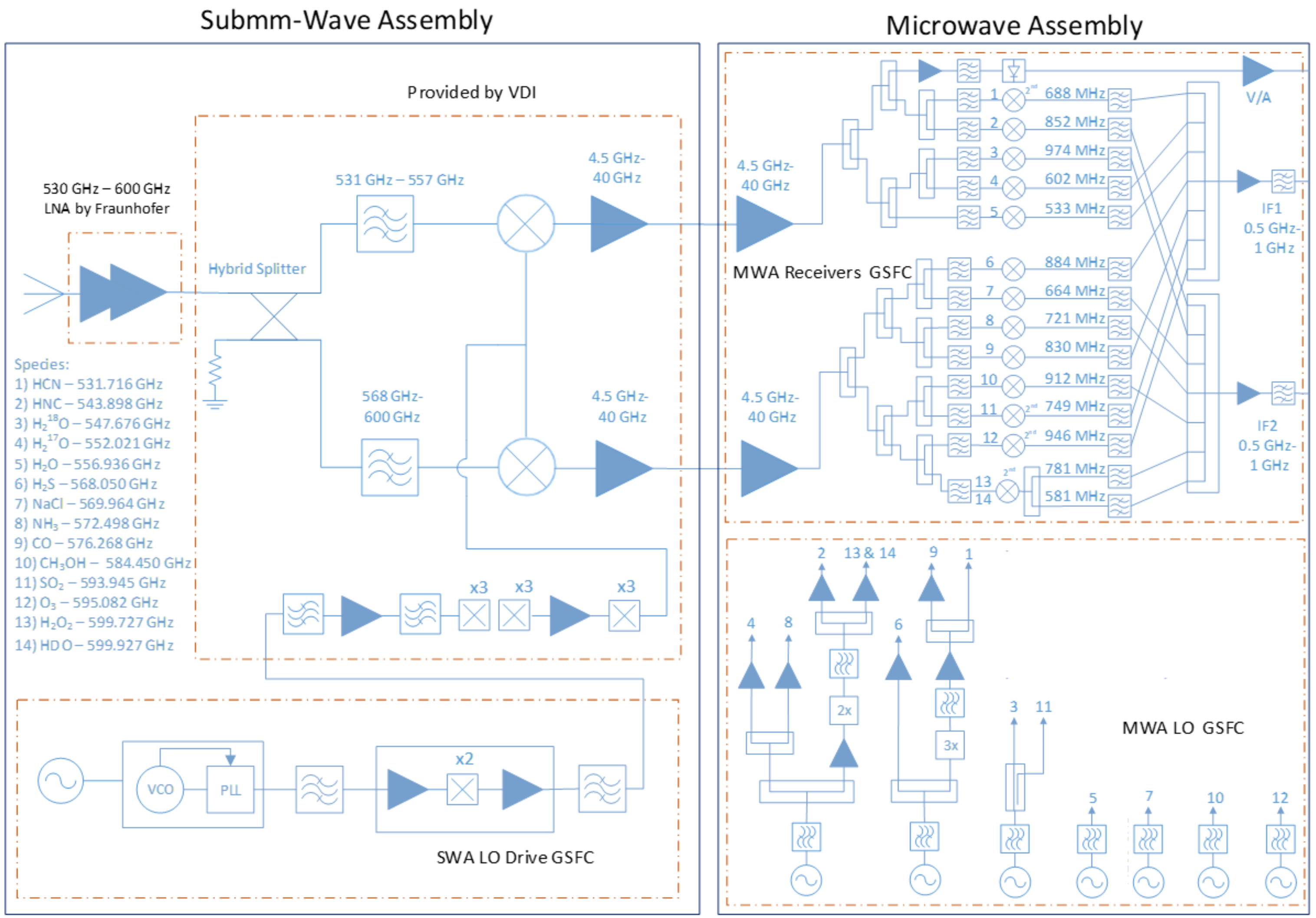
- Advance the TRL of RF Low Noise Amplifier (RF LNA)
  - Optimize Noise Figure & Gain
- Advance TRL of Mixer & LO Assembly (MLA)
  - Partnership with Virginia Diodes, Inc. via Phase 3 SBIR
- Design, build and test Microwave Assembly (MWA)
  - In-house build leveraging COTS where possible
- Design, build and test Digital Spectrometer Assembly (DSA)
- Raise TRL to 6 of SELFI RF-to-Digital Spectrometer through functional and environmental testing
  - Reduce risk of flight instrument development



Advance our technical capabilities, reduce technical risks and gain the knowledge necessary to build an instrument to make submm spectroscopic measurements of Enceladus plumes

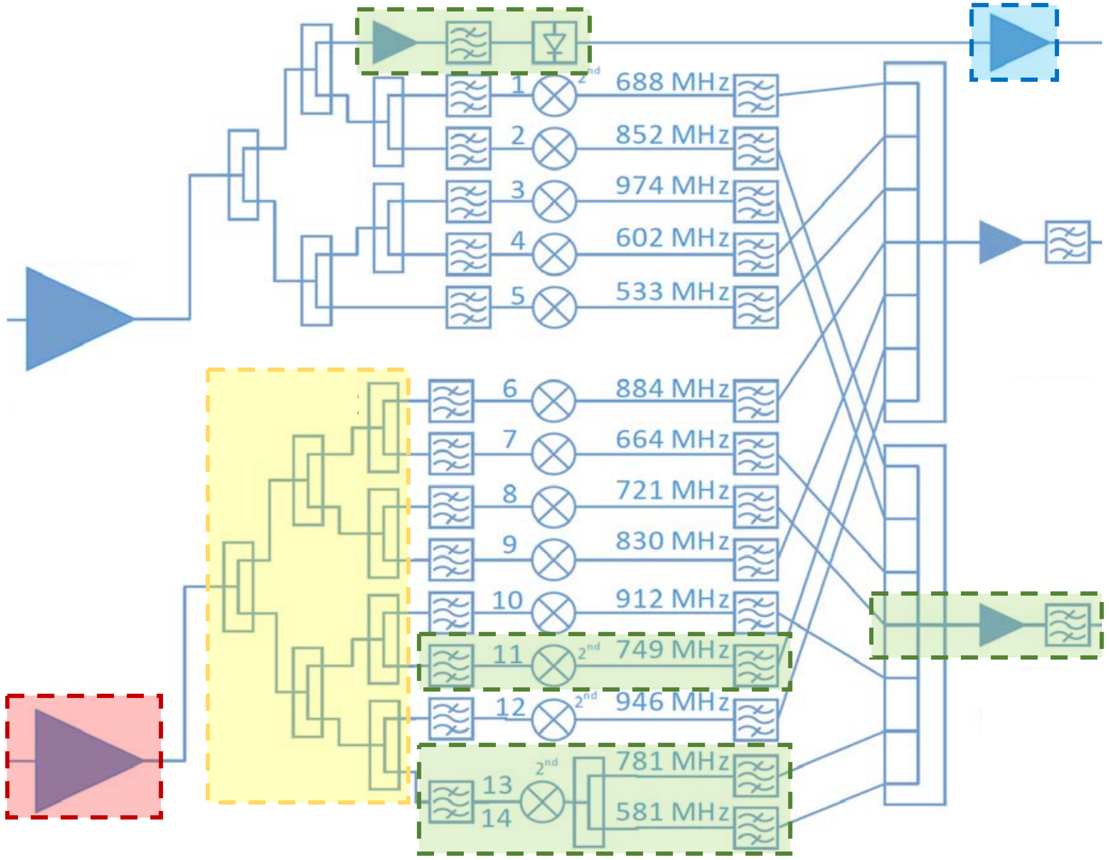
RF System Architecture

- Cascaded RF LNA has > 20 dB gain and < 12 dB NF
- Hybrid Coupler and dual-mixer downconverts upper/lower sidebands into two 35 GHz IF bands
- Submm-Wave Assembly (SWA) LO Drive provides frequency switching for baseline subtraction
- Microwave Assembly downconverts 14 species into two 500 MHz bandwidths



MWA Receiver Prototype Approach

- Insufficient schedule and budget for full MWA receiver prototype.
- Cascade 4 connectorized prototypes
  - 3-Stage Cascaded LNA
  - 8-Way Cascaded Wilkinson
  - Receiver Chain
  - Video Amplifier (Durachka/564)
- Characterize end-to-end performance
  - Gain, Return Loss, and Isolation
  - Noise Figure
  - Linearity and Compression
  - Performance vs Temperature (schedule permitting)
- Enables full characterization of system end-to-end performance in selected subset bands



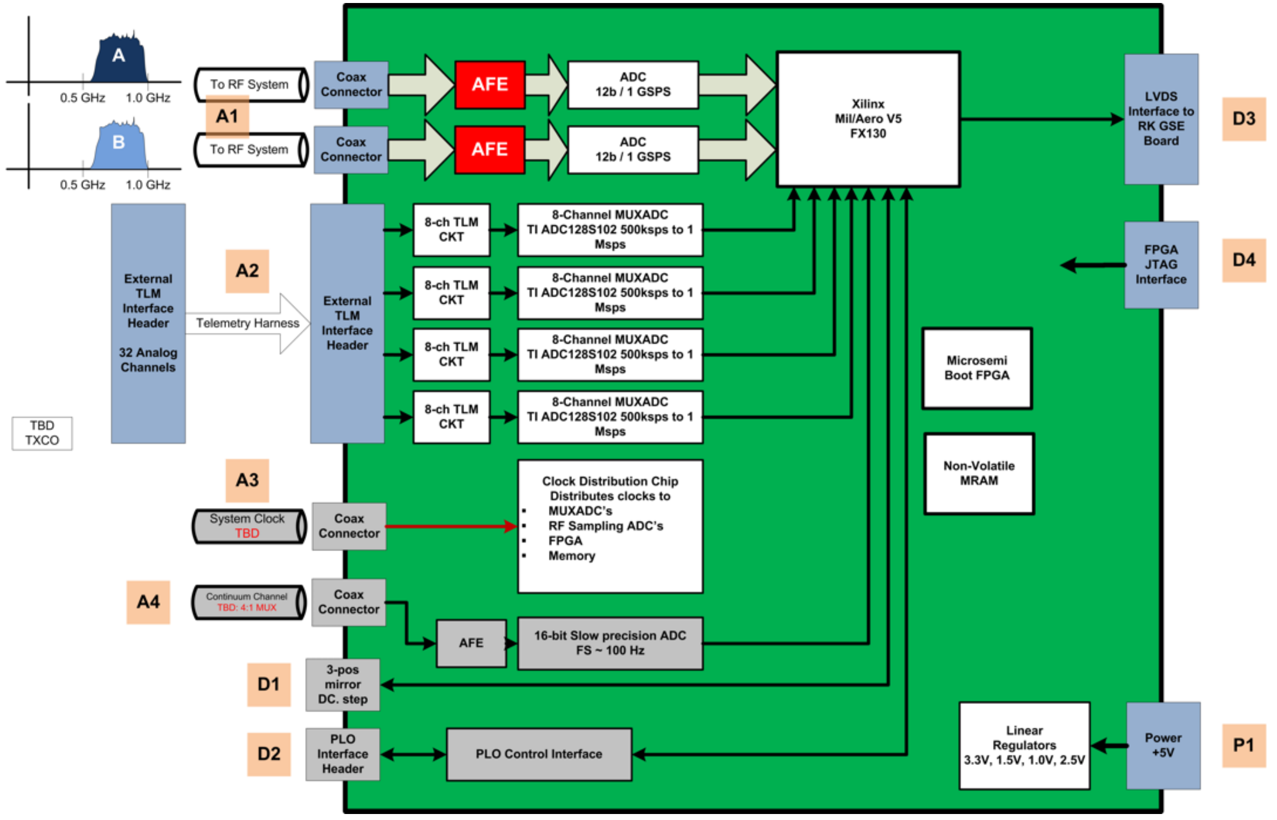
Legend:
- 3-Stage Cascaded LNA Prototype
- 8-Way Cascaded Wilkinson Prototype
- Receiver Chain Prototype
- Video Amplifier Prototype

All prototype circuits designed and currently in various stages of fabrication and test

SELFI Digital Spectrometer Assembly

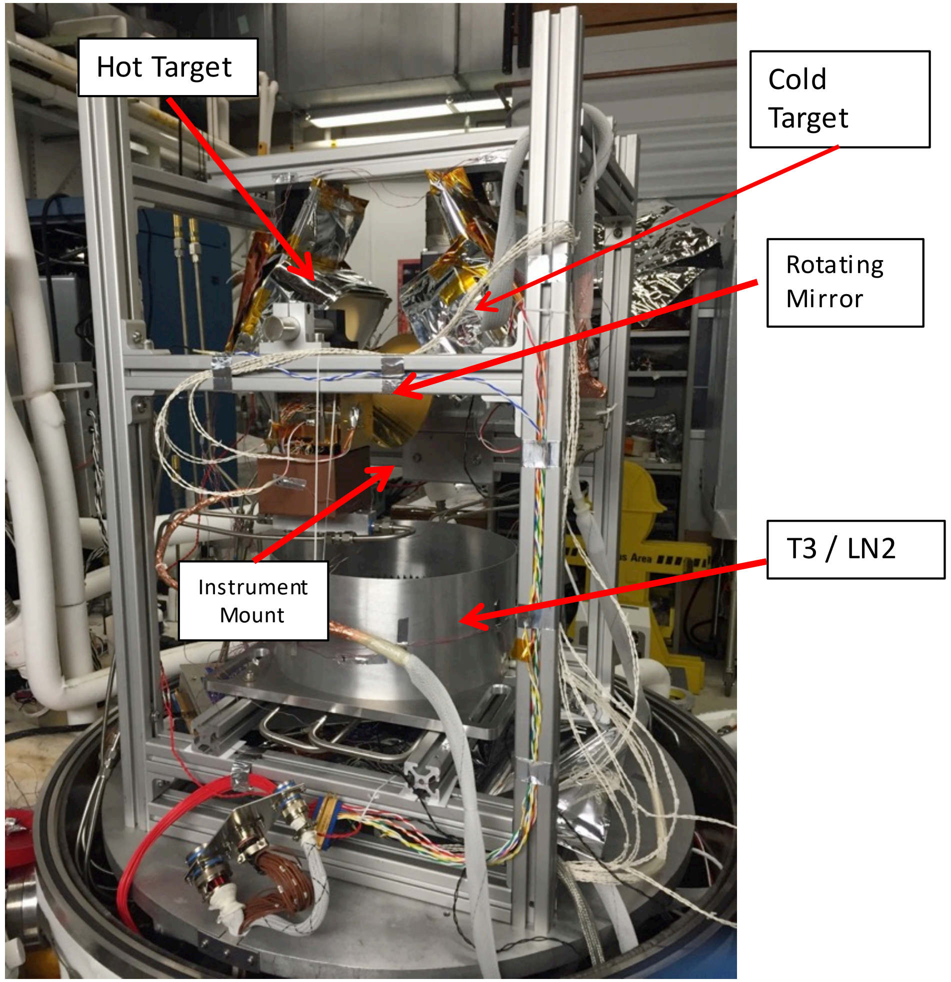
- SELFI will use a build-to-print copy of the GEDI Digital Unit
  - Offers TRL-6 solution to implementing SELFI digital spectrometer; reduces project risk
  - Accelerates delivery of SELFI digital spectrometer by approximately 1 year
  - Provides platform for algorithm testing and optimization
  - Eliminates the need for custom GSE to be developed for DSA. Uses GEDI infrastructure, including infrastructure for thermal testing.
  - Eliminates need for complex PCB layout otherwise required for SELFI DSA implementation.
- Changes required
  - Analog front-end (AFE) compatible with SELFI RF system
  - Requires separate telemetry/interface board
- Deliver GEDI DU copy to project, May 2019; Delivery telemetry/interface board, December 2019

Global Ecosystem Dynamics Investigation (GEDI) Digital Unit



I&T Calibration Fixture

- Sub-MMW Calibration Fixture
  - Developed Sub-mmwave calibration fixture in 2015/2016 for the IceCube mission.
  - Vacuum-rated 3 temperature-stabilized targets, with rotating mirror
  - Targets spec'd 250 GHz – 1 GHz, made by ZAX millimeter wave corporation



Accomplishments to Date (first 15 months)

- Completed architecture study that resulted in a simpler implementation and improved science; expanded detection bandwidth and added HCN as 14th species
- Established Level 1 & 2 system requirements. Updated Level 2. Developed Level 3 and 4 requirements.
- Demonstrated spectrometer algorithm on GEDI engineering test unit
- Adopted TRL 6 GEDI design to meet project requirements for digital spectrometer
  - Initiated build of GEDI Digital Unit
  - Prototyped and tested Analog Front End
- Specified requirements for telemetry data; Developed initial telemetry board design
- Accelerated LNA and Receiver procurements into Year 1
  - VDI Small Business Innovation Research (SBIR) Phase 3 awarded along with $185K SBIR Phase 2E match
  - Awarded contract for LNA procurement
- Defined architecture of SELFI mixer and LO assembly
- Developed requirements for Power Distribution Unit
  - Contracted with grounding expert consultant
- Designed, built and tested prototyped Submillimeter Wave LO Drive
- Developed design of Microwave Assembly
  - Identified circuits to be prototype, developed designs and ordered test circuits
- Team is working toward Critical Design Review in July 2019


Questions ???