Compact Radar for Measurements of Clouds, Convection and Precipitation

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Program: Strategic Initiative

Project Objective:

Develop a multi-frequency millimeter-wave (Ka-, W- and G- band) radar system using an architecture that will result in small mass, power and size. The instrument will facilitate a low-cost Clouds, Convection and Precipitation (CCP) mission concept compatible with a small and low-cost spacecraft platform. We will demonstrate and validate the performance of the multi-frequency operation of the radar system, by carrying out measurements of the different subsystems and the instrument as a whole. We will provide an airborne prototype radar that will be able to demonstrate the instrument capability.

Approach:

The instrument developed under this task, is composed of mature solid-state components integrated in a compact architecture, analogous to RainCubes', where the baseband signal will be directly upconverted to the RF band without any addition of intermediate frequencies or further multiplication scheme. This novel architecture provides a simple and effective solution while achieving the required performance and robustness of an airborne or space flight radar instrument.

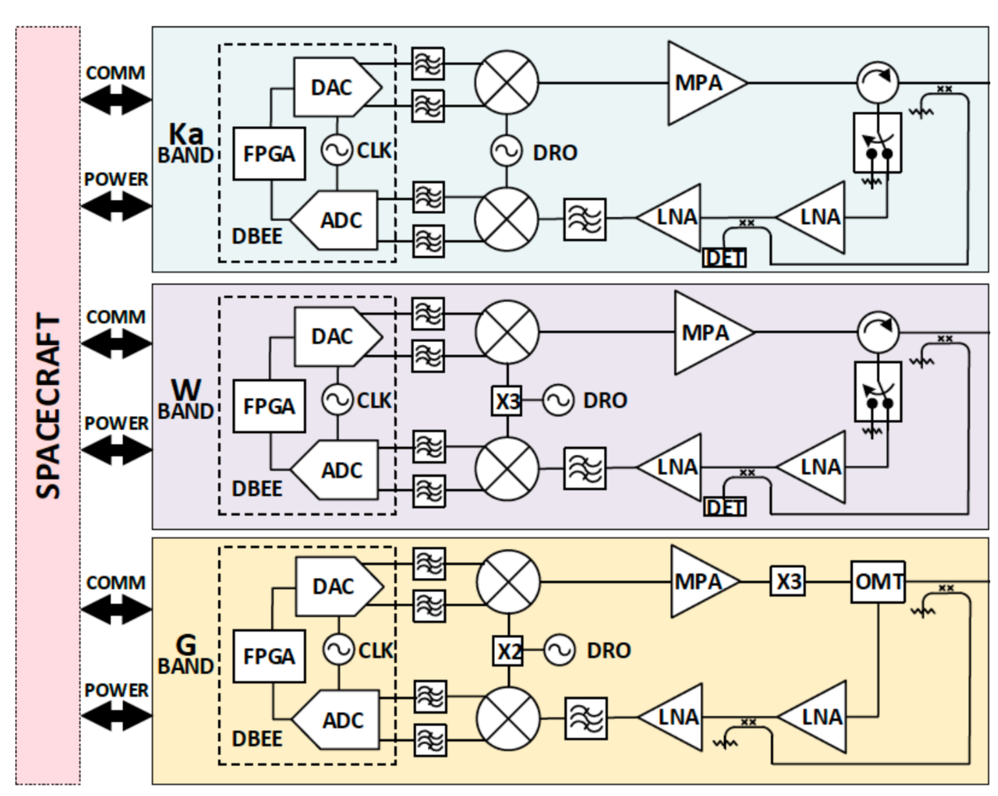

Figure 1. Simplified block diagram, including the three frequency RF modules.

Benefits to NASA and JPL:

Compact and affordable radar instruments facilitate the deployment of constellations of identical instruments flying in Low Earth Orbit (LEO). Low cost constellations can fly in formation to observe the evolution of weather processes with high-vertical resolution profiling capabilities or in diverse orbits to increase sampling across the diurnal cycle. This work will facilitate proposals to the upcoming EVM and EVI instrument calls, as well as offer competitive and timely "out of the box" candidate solutions for the implementation of specific aspects of the CCP Designated Observable and PBL Targeted Observables. Successful completion of the current task will permit a variety of mission architectures including any combination of the Ka/W/G band channels on a small satellite platform.

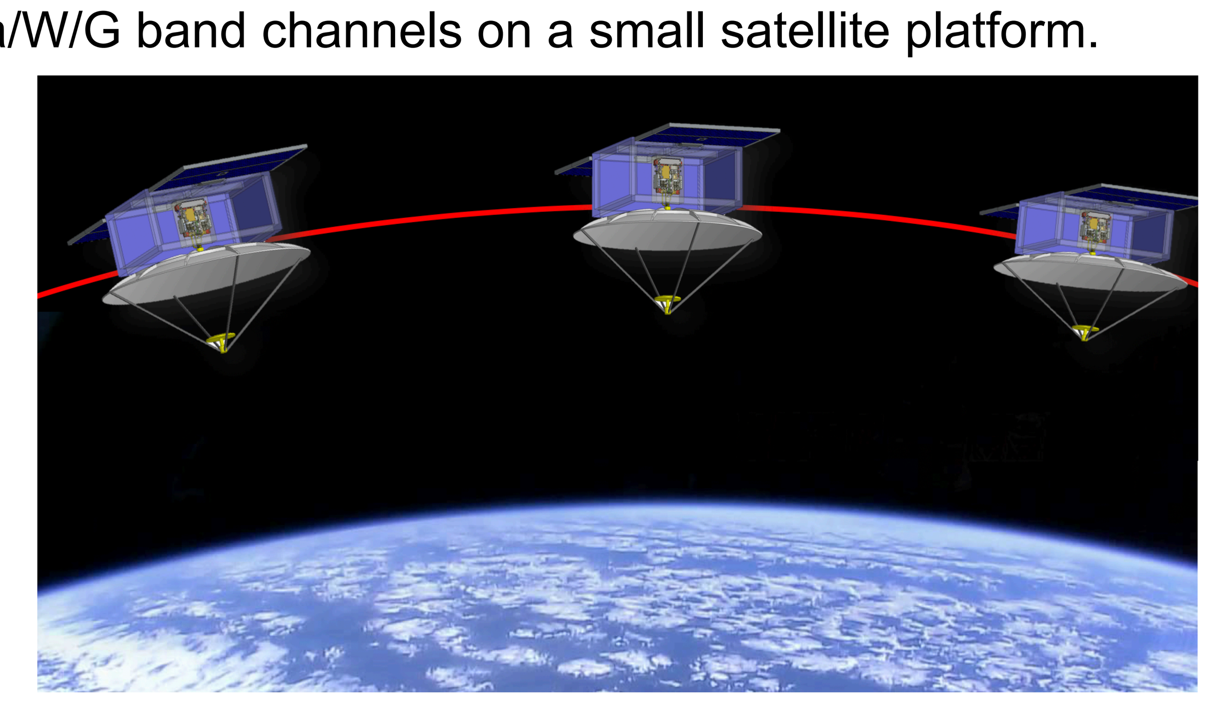

Figure 2*. Illustration* of a future mission concept of a low-cost constellation of SmallSats enabled by this task development.

FY18/19 Results:

After the characterization of the individual components, the first radar prototype was assembled and tested in the lab. First outdoor tests were made in May, 2019 with the successful detection of different targets as clouds and buildings (Figure 6 middle and right, respectively). The tests validated the pulse compression optimization for sidelobe suppression [6] to better than 65 dB for ranges above 1 km from the surface, see Figure 6 (left). These sidelobe levels are sufficiently low to ensure the surface response's sidelobes are below the threshold required for cloud detection.

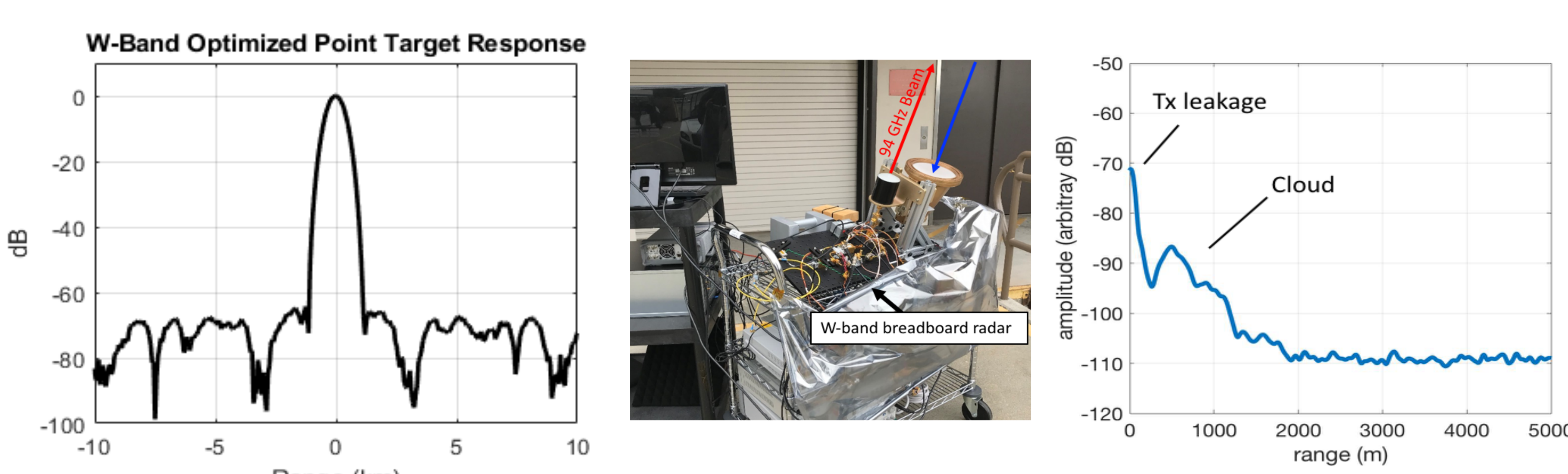

Figure 3. Left, W-band radar's optimized pulse compression point-target range response for a 0.6 km range-resolution pulse. Center, a 94 GHz breadboard radar on a test cart pointing to a cloud. Right, range spectra showing the detection of clouds at ranges between 500 to 1500 m using a 60 m range resolution pulse.

The next step is to implement monostatic radar operations using a single aperture. To provide high transmit/receiver isolator we will use compact, latching ferrite circulator switch assemblies that allow for more than 80 dB of transmit/receive isolation. We have built a radar prototype using as primary mirror an already existing ellipsoidal mirror with discrete radar components and one of JPL's designed PA (1 Watt peak power) and pulsed power supply. We are currently testing the system in the lab, see Figure 4.

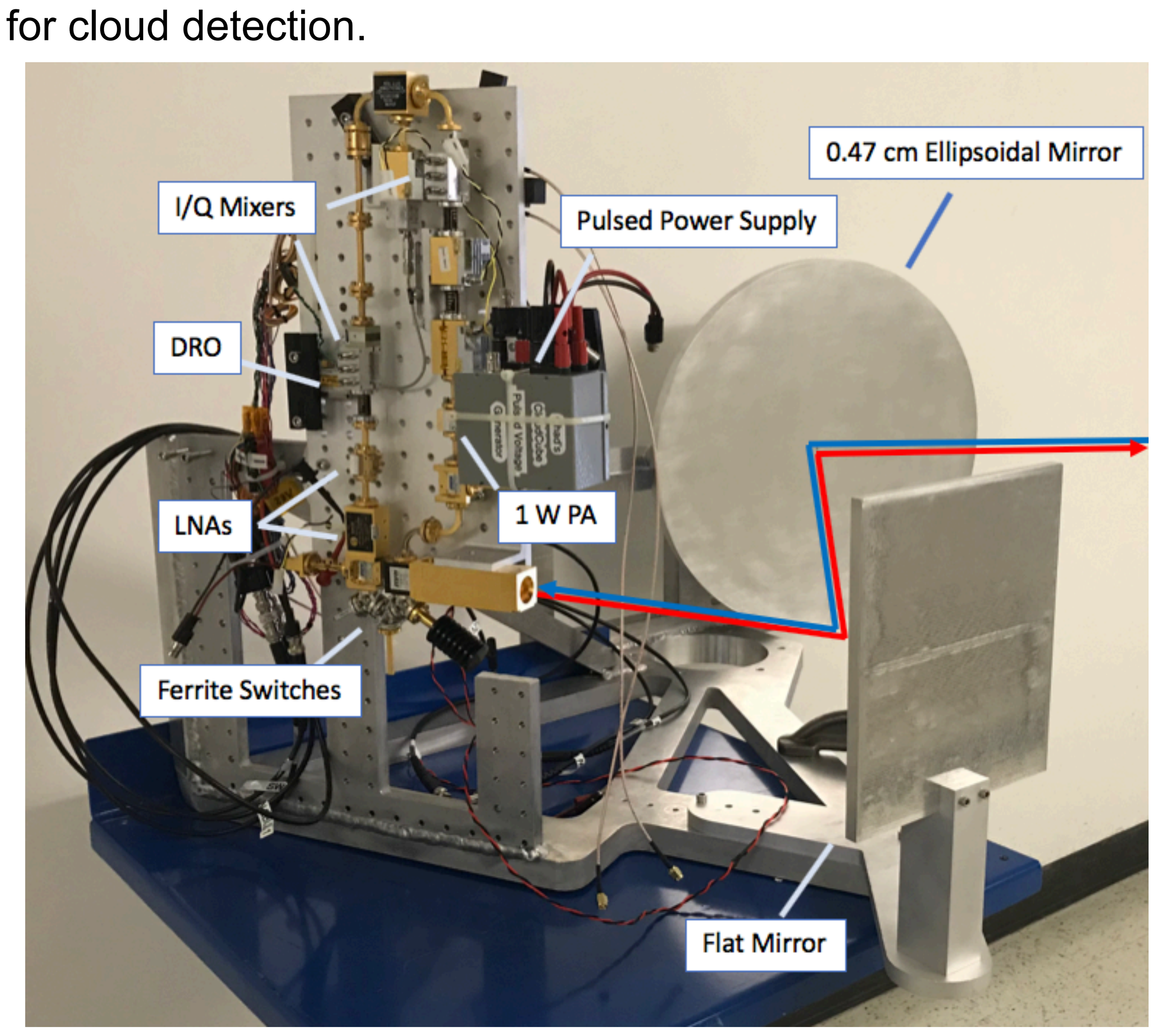

Figure 4. Monostatic W-band radar breadboard.

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