National Aeronautics and Space Administration

NORTHROP GRUMMAN

TECHNOLOGY DEVELOPMENT FOR 3-D WIDE SWATH IMAGING SUPPORTING ACE

Presentation to the ACE Science Working Group

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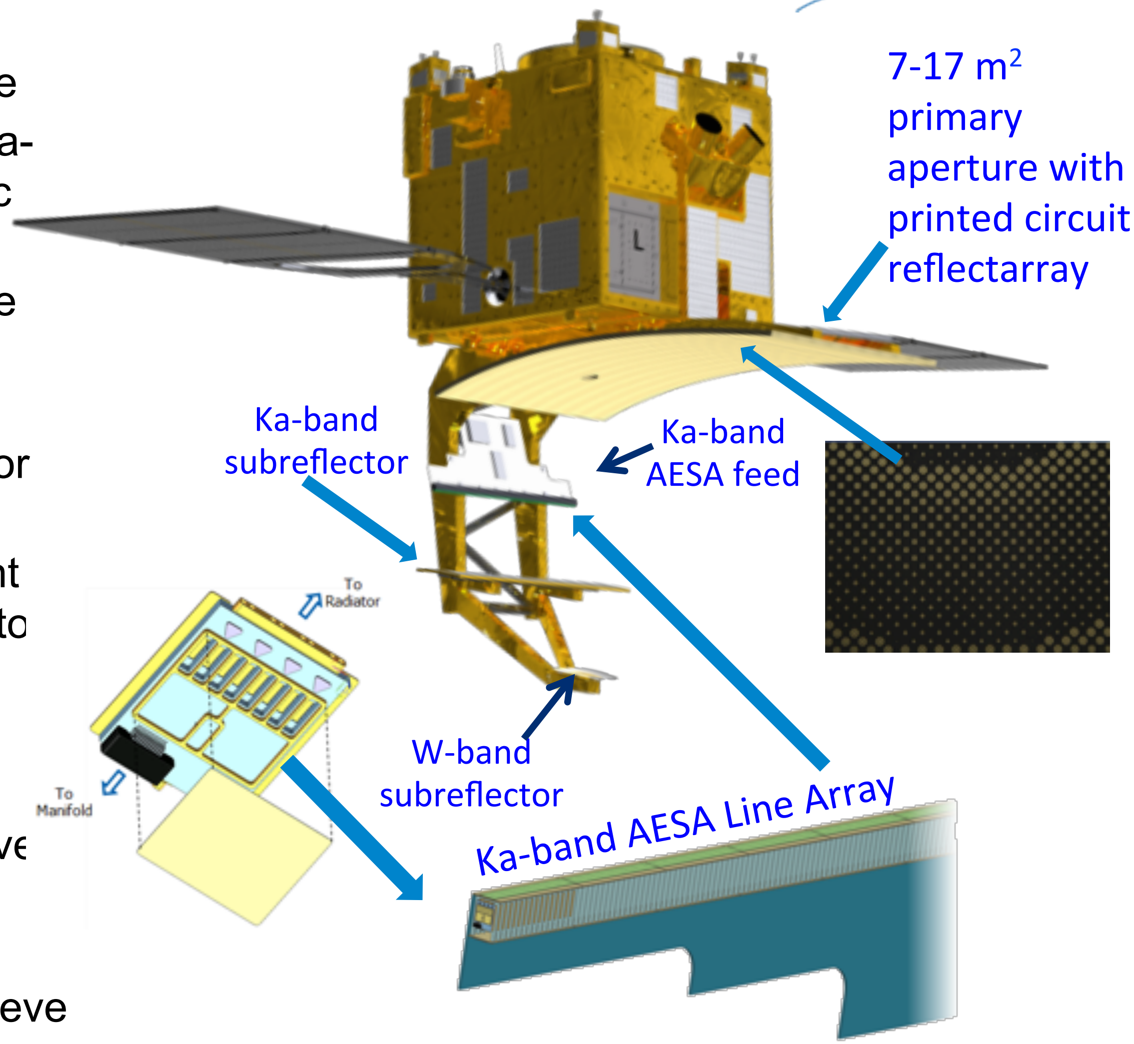
Outline

- ACE Radar Introduction
- Overview of 2010 IIP objectives
- Reflectarray Development
  - IPHEX/RADEX Reflectarray Airborne Demonstration
- ACE Radar Design Study
- TRL Assessment & Technology Maturation Plan
- 2013 IIP Summary

Introduction to Dual Band ACE Radar

Discriminating Features

- Shared Dual-Band Primary Aperture
- Wide swath imaging (≥120km) at Ka-band enabled by Azimuth Electronic Scanning (AESA Feed)
- Fixed Beam at W-Band (Compatible with CloudSat / EarthCare Beam Waveguide and Transceiver)
- Reflectarray enables tri-band and/or scanning W-band options
- Significant Payload Size and Weight Savings (Compared with two-reflecto solution)
- Leverages TRL 6+ W-band Space Radar
- Leverages HIWRAP/CRS Transceive and Advanced Signal Processing Algorithms
- Technology Maturation Plan to achieve TRL 6 by 2017

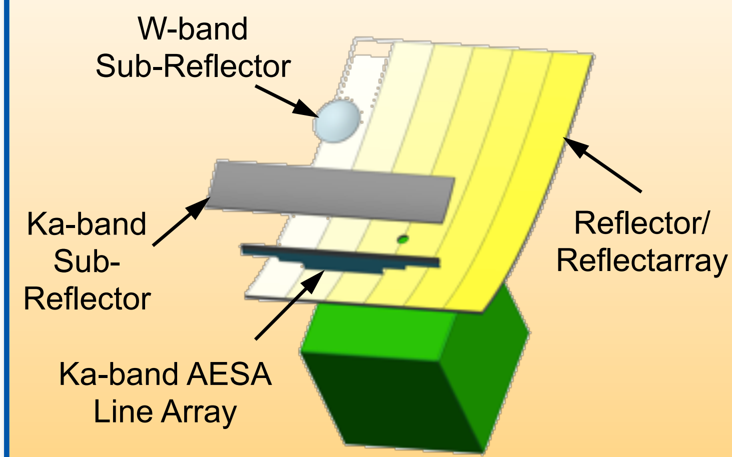


ACE Radar 2010 Instrument Incubator Program

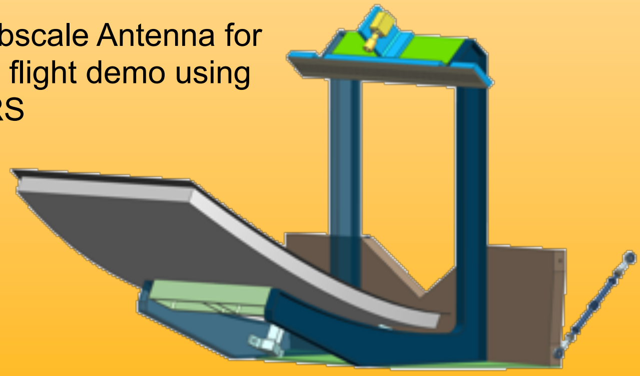
Project Objectives

- Develop design and analysis tools for dual-band reflectarrays. Validate tools and models using at 35 GHz (Ka-band) and 94 GHz (W-band) using test coupons. ***Testing complete, Oct. 2012.***
- Develop subscale reflector/reflectarray model for dual-band range pattern testing. Integrate and test subscale model with CRS in airborne flight to demonstrate dual aperture performance. ***Test flight, Apr., 2014 and IPHEX science flights, May-Jun. 2014.***
- Develop preliminary design of full scale antenna, Ka-band AESA module, and feed to identify key technology trades and drivers. ***Full-scale PDR, Nov. 2012, Ka-band AESA PDR, Jan. 2013.***
- Design, fabricate, and test Ka-band MMIC front end for AESA module. ***Ongoing.***

GSFC/NGES ACE Cloud Radar using Reflector/Reflectarray Technology for wide swath Ka-band profiling



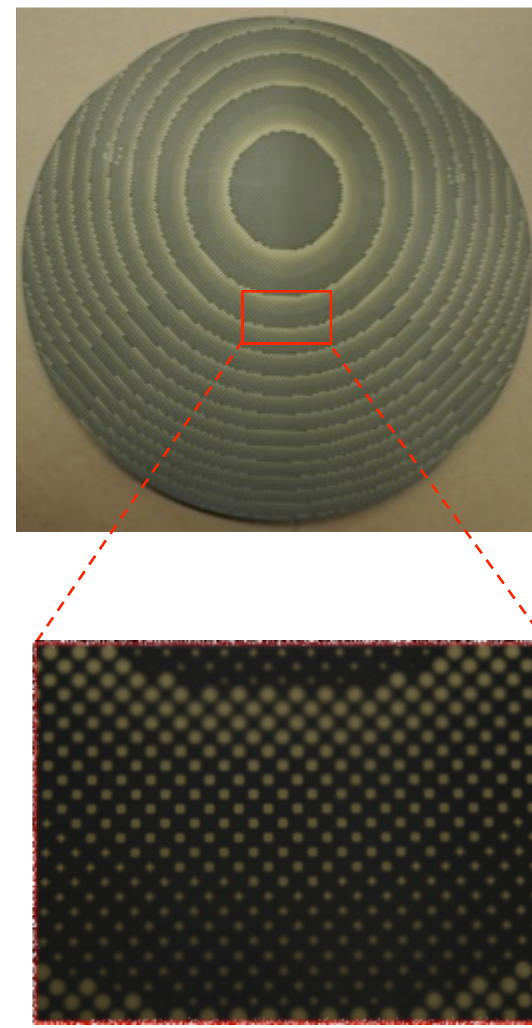
Subscale Antenna for a/c flight demo using CRS



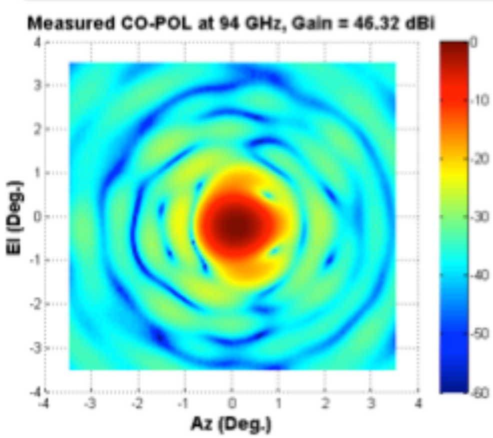
Reflectarray Technology Development & Airborne Demonstration

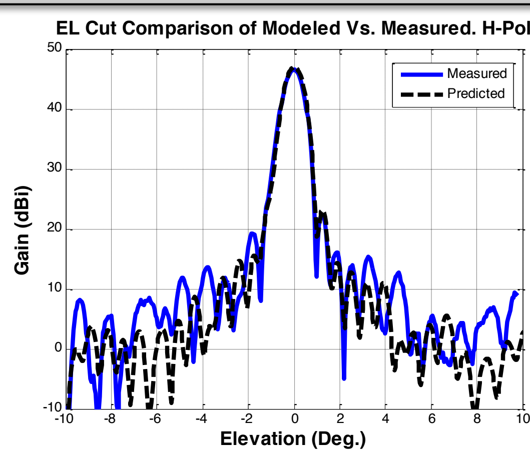
Planar Reflectarray Coupon Demonstration

- Flat Coupons validated reflectarray RF models
  - Reflectarray analysis/synthesis model (MATGO) and Element models
- Demonstrate manufacturability of reflectarray PCBs on candidate materials
- Demonstrate basic reflector/reflectarray functionality
  - Reflectarray focusing at W-band
  - FSS transparency at Ka-band



Measurements validate predicted performance

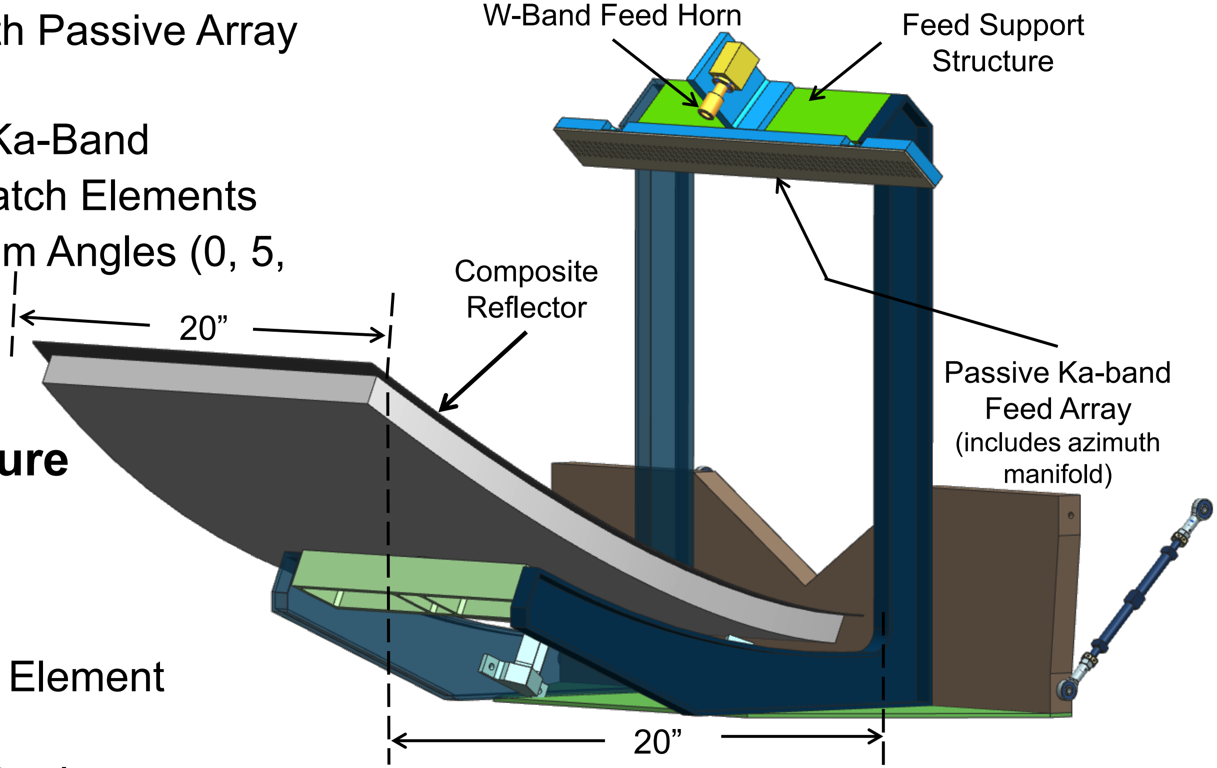




Sub-Scale Demo Design/Architecture

Ka-Band Antenna Architecture

- 35.5 GHz Operating Frequency
- Parabolic Cylinder Reflector with Passive Array Feed
- W-Band Reflectarray - FSS at Ka-Band
- Array Feed - Dual Pol 4 x 64 Patch Elements
- 3 Manifold Designs - Fixed Beam Angles (0, 5, 10 degs)



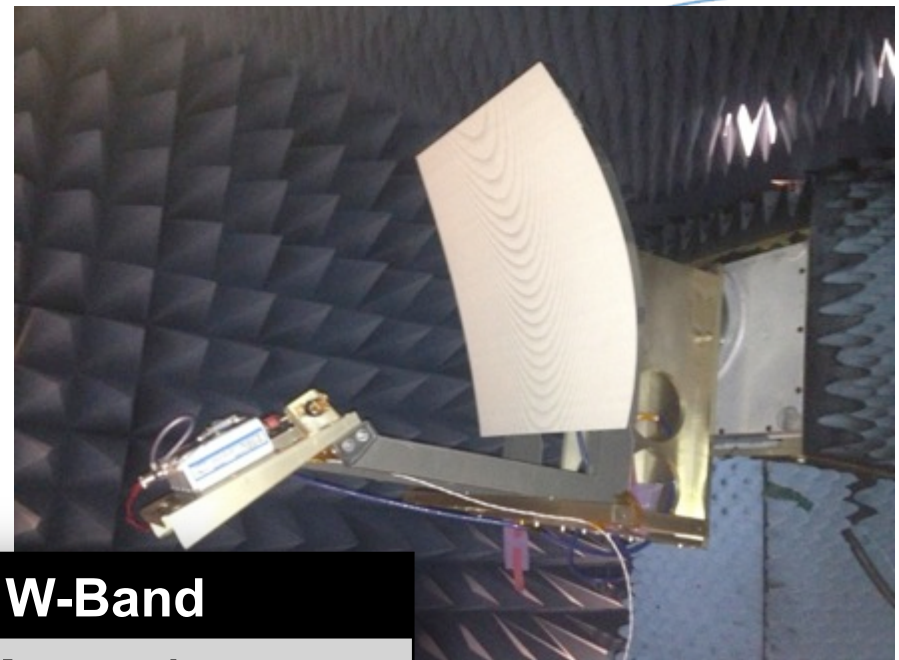
W-Band Antenna Architecture

- 94 GHz Operating Frequency
- Parabolic Cylinder Surface w/ Reflectarray to Focus Beam
- Reflectarray Uses Hybrid Loop Element on Rogers 6002
- Scalar Horn Feed with OMT (Dual Linear Pol)

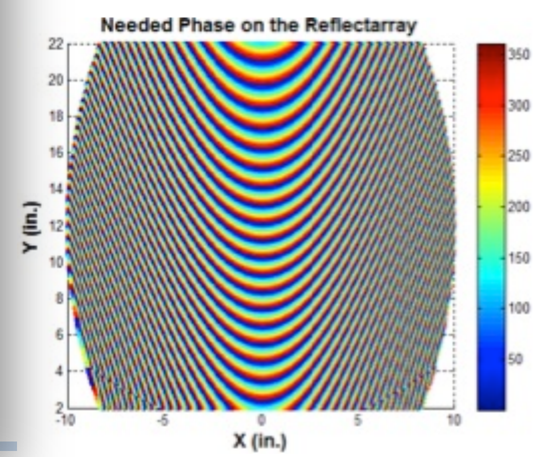
Sub-Scale antenna has been successfully tested on ER-2 with CRS and is currently flying for IPHEX/RADEX mission

Sub-Scale Demo Design/Architecture

Loss Budget for W-Band Antenna	
Aperture Directivity:	54.4 dBi
Taper Loss:	1.5 dB
Spillover:	0.4 dB
Phase Error Loss:	0.3 dB
Absorptive Loss:	0.6 dB
Gain:	51.7 dBi



Performance Summary for W-Band	
	Measured:
VPOL (Co) Realized Gain:	51.1 dBi (94.05 GHz)
HPOL (Co) Realized Gain:	50.9 dBi (94.05 GHz)
Az Beam Width:	0.45° (V) / 0.47° (H)
El Beam Width:	0.47° (V) / 0.48° (H)
Cross-Pol (dB):	-33.2 (V) / -28.6 (H)
Peak Az Side Lobe (dB):	-28.8 (V) / -26.9 (H)
Peak El Side Lobe (dB):	-27.2 (V) / -29.5 (H)



The GPM Integrated Precipitation and Hydrology Experiment

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Goddard Microwave Instruments

ER-2 Instruments

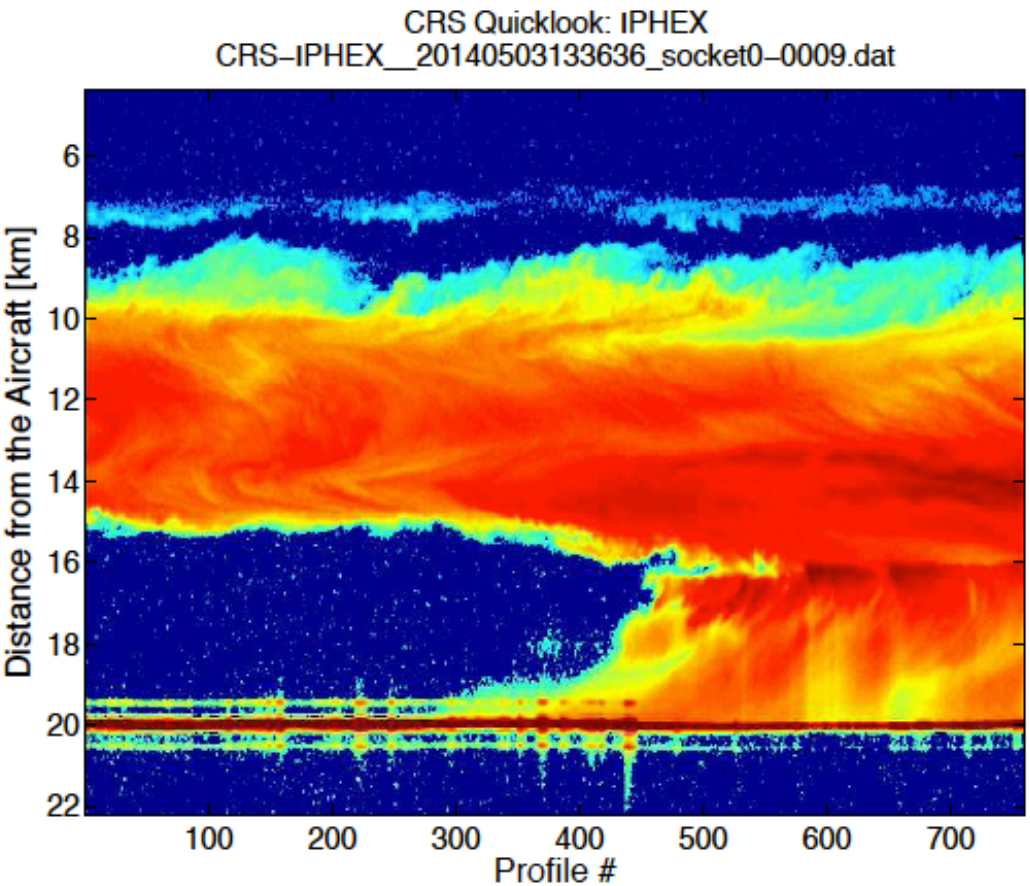
HIWRAP (Radar)	13.91/13.47 GHz, 35.56/33.72 GHz
EXRAD (Radar)	9.626 GHz (nadir); 9.596 GHz (scanning)
CRS (Radar)	94.15 GHz (dual-polarized)
CoSMIR (Radiometer)	53 (x3), 89, 165.5, 183.3+/-1, 183.3+/-3, 183.3+/-8 GHz

Ground-based Instruments

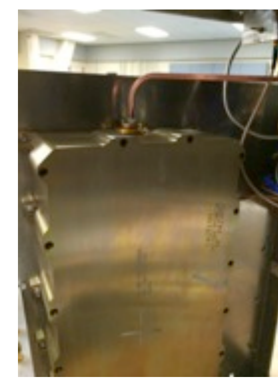
N-POL (Radar)	2.8 GHz
D3R (Radar)	13.91 GHz, 35.56 GHz
ACHIEVE (Radar)	10, 24, 94 GHz
DoER (Radiometer)	22 (x5), 37, 89 GHz

CRS flights funded through IIP and RADEX

First Quick-look Imagery from CRS



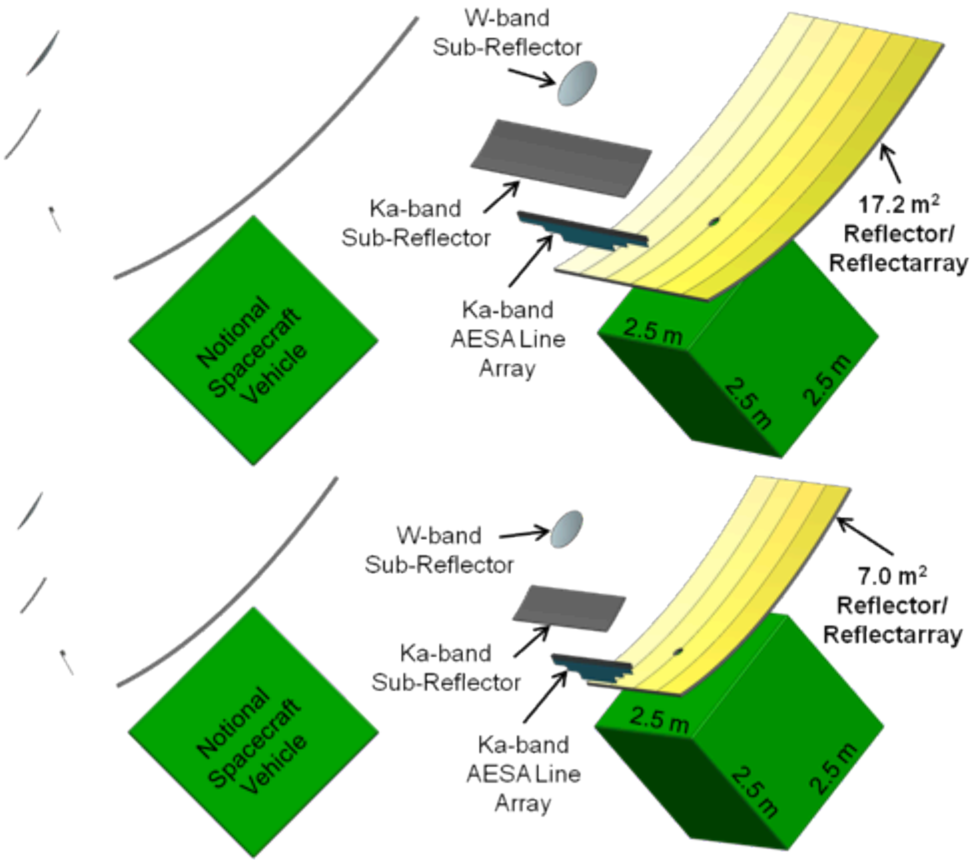
Sub-scale antenna in CRS canister in ER-2 tail cone



SSPA installed in CRS

ACE Radar Design Study

Full-Scale Antenna Trades
Shown Relative to Notional Space Vehicle



4.15 x 4.15 m^2 Projected Aperture:

Reflector/Reflectarray:
Cassegrain Folded Optics

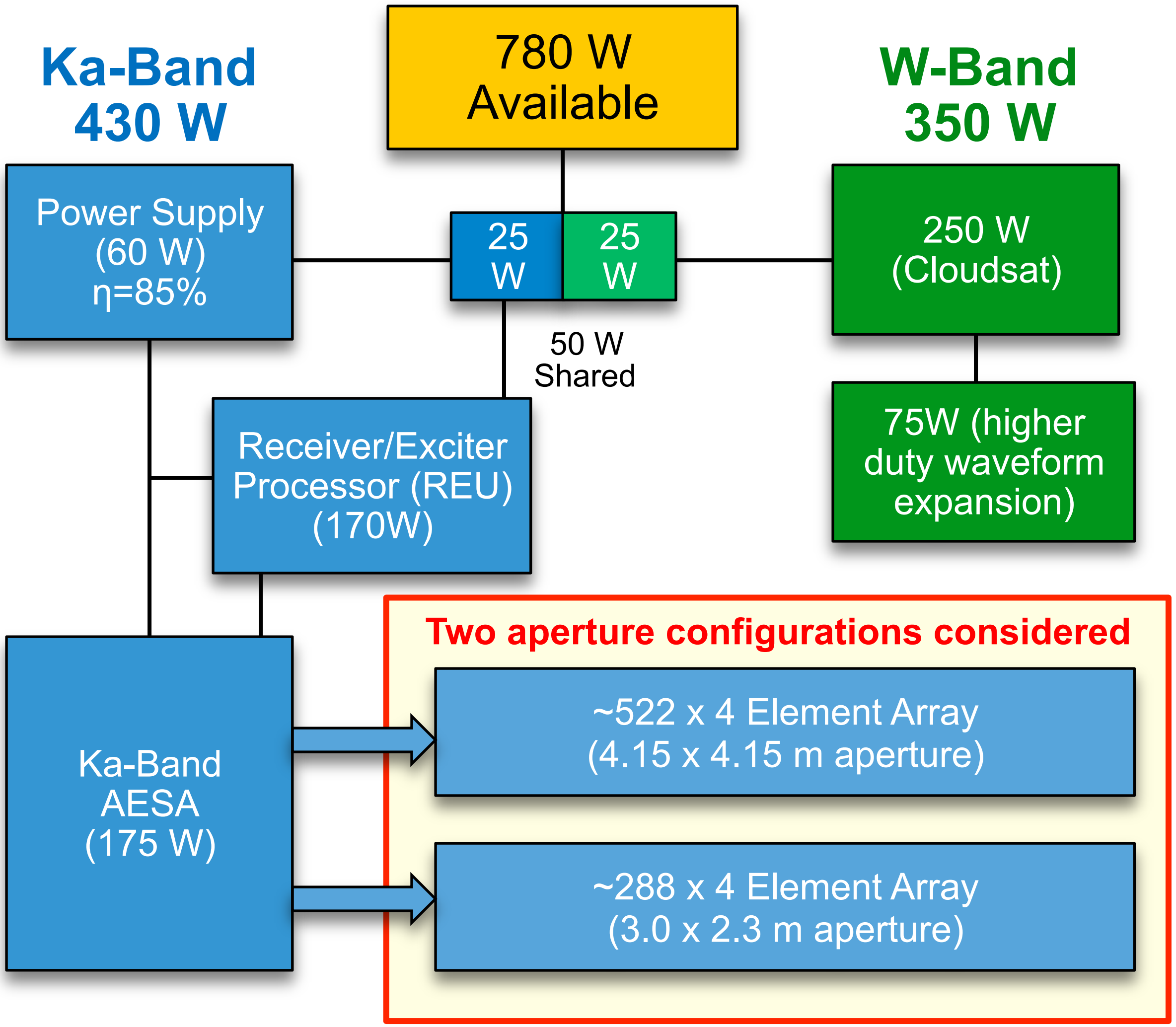
2.33x 3 m^2 Projected Aperture:

Reflector/Reflectarray:
Cassegrain Folded Optics

Full-Scale Design is Modular and Scalable… It Leverages RF Design, Mechanical Design and Manufacturing Processes Developed for Coupon and Sub-Scale Designs

Assumed Power Allocation for Radar Design and trade studies

- Power availability on spacecraft affects the achievable performance and influences the radar design, especially the AESA
- Selected 780W to be consistent with GPM/DPR
- Evaluated performance of two aperture sizes using the same available power
- Evaluated how design of the AESA was influenced by available prime power



Aperture Size – Performance and Cost Driver

Performance Trades between Two Aperture Sizes		
	7 m^2 Aperture	17 m^2 Aperture
Ka-Band Resolution	Meets Requirement	Meets Goal
Ka-Band Sensitivity (off Nadir)	-10.2 dBZ (Meets Requirement)	-13.9 dBZ (Meets Requirement)
Ka-Band Doppler	1 m/s (Meets Requirement)	0.5 m/s (Meets Goal)
W-Band Resolution	Meets Goal	Meets Goal
W-Band Sensitivity	-33.6 dBZ (Marginal to Requirement)	-37.4 dBZ (Meets Requirement)
W-Band Doppler	0.4 m/s (Meets Requirement)	0.2 m/s (Meets Goal)
Mass (Kg)	325 - 375	500 - 600

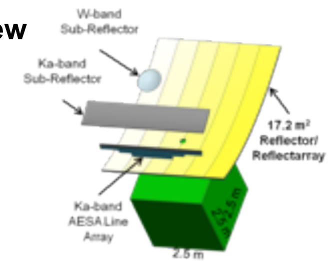
Aperture size drives cost, performance, and spacecraft packaging

TRL Assessment & Technology Maturation Plan

Technology Maturation Plan (TMP) Radar System Study & 5 Areas Addressed Keyed to Major Subsystems on Radar TRL Block Diagram

0. Concept Study and System Design Review

a) Requirements update
b) Review major trades
c) System Design Study
d) Software Assessment
e) System Design Review (SDR)



1. Dual Band Antenna

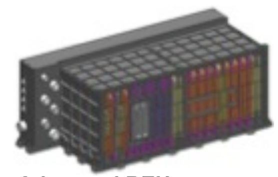
a) Primary reflector
b) Reflectarray/Frequency Selective Surface (FSS)
c) W-band Subreflector
d) Ka-band Subreflector
e) Support structures

2. Ka-Band AESA Feed

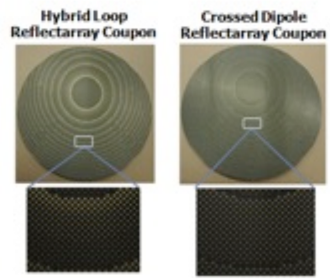
a) Passive Manifold and Radiator
b) AESA Coldplate (thermal control)
c) AESA Beam Steering Control
d) AESA Power Supplies
e) T/R Modules
f) Active Feed Structure

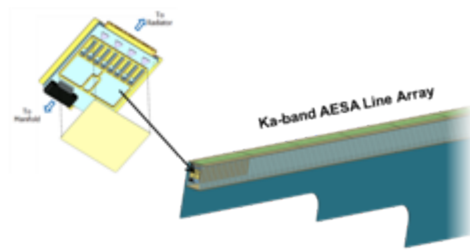
3. W-band Transceiver

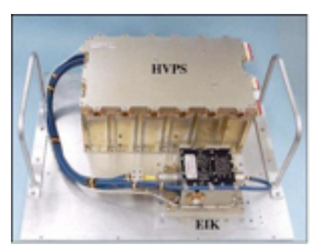
a) Transmitter – EIK baseline
   Option: SS Transmitter
b) Receiver - LNA
c) Quasi-optical Transmission Line (QOTL)
d) Power Supplies
   Option: Active Feed & Beam Steering Control



Advanced REU







4. Radar Electronics Unit: RF, Waveform, and Frequency conversion

a) Master Oscillator
b) Reference Generator
c) Waveform generator
   i. Hardware
   ii. Algorithms
   iii. Firmware
d) Frequency Plan
e) Up/Down RF-IF Frequency Conversion
f) Analog Power Supplies
g) Backplane
h) Chassis
i) Thermal
j) Form Factor

5. Radar Electronics Unit: Signal Processing and Control

a) Digital Receiver (multi-channel configuration)
b) Algorithms and Firmware
c) Interface & Timing
d) Power Supply
e) Onboard processor
   i. Hardware
   ii. Radar control algorithms
   iii. Software

2013 ACE Radar IIP

Wide-swath Shared Aperture Cloud Radar (WiSCR), 2013 IIP Award

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Advance Readiness of Scanning AESA Feed - Ka-Band T/R Module Tasks

- Develop design of Space-Qualifiable Ka-band AESA T/R Module Package with (new design) Integrated RF Circulator
- Design, fabricate and test Ka-band circulator coupon
- Design, fabricate and test Ka-band T/R Module GaAs LNA, Switch and Multifunction Phase/Atten MMICs, second iteration of GaN HPA, Si ASICs for power and amp/phase control.

Tri-band Antenna Concept (Ku/Ka/W)

- Evaluate performance of W-band fixed vs scanning feed
- Study trade between single Ku/Ka-band line feed vs. separate feeds
- Study trade, separate vs. shared subreflectors

Wide-swath Shared Aperture Cloud Radar (WiSCR), 2013 IIP Award Tasks (Cont'd)

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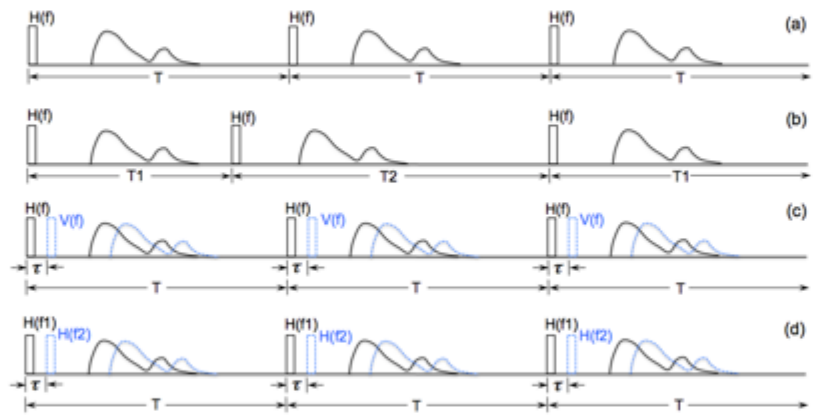
Frequency up/down converter

- Design and fabricate Multi-channel Frequency Conversion Module (MFCM)
- Design and fabricate Multi-channel Arbitrary Waveform Generator (MAWG)
- Airborne flight demonstration of MFCM and MAWG

Advanced Doppler Processing Algorithms

- Develop Frequency Diversity Pulse Pair (FDPP) processing
- Noise assisted I-Q data analysis
- Airborne demonstration of FDPP algorithm

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Thank You!