Active microwave sensors have proven to be ideal instruments for many Earth science applications. Examples include global freeze and thaw monitoring, soil moisture mapping, accurate global wind retrieval, and snow inundation mapping, global 3D mapping of rainfall and cloud systems, precise topographic mapping and natural hazard monitoring, global ocean topographic mapping, and glacial ice mapping for climate change studies. For global coverage and the long-term study of Earth's eco-systems, space-based radar is of particular interest to Earth scientists. Radar instruments for Earth science measurements include Synthetic Aperture Radar (SAR), scatterometers, sounders, altimeters, and atmospheric radars. The life-cycle cost of such radar missions has always been driven by the resources-power, mass, size, and data rate-required by the radar instrument, often making radar not cost competitive with other remote sensing instruments. Order-of-magnitude advancement in key sensor components will make the radar instrument more power efficient, much lighter weight, and smaller in stow volume, leading to substantial savings in overall mission life-cycle cost by requiring smaller and less expensive spacecraft buses and launch vehicles. Onboard processing techniques will reduce data rates sufficiently to enable global coverage. High performance, yet affordable, radars will provide data products of better quality and deliver them to the users more frequently and in a timelier manner, with benefits for science as well as the civil and defense communities. Technologies that may lead to advances in instrument design, architectures, hardware, and algorithms are the focused areas of this subtopic. In order to increase the radar remote sensing user community, this subtopic will also consider radar data applications and post-processing techniques.

The frequency and bandwidth of operation are mission driven and defined by the science objectives. For SAR applications, the frequencies of interest include UHF (100 MHz), P-band (400 MHz), L-band (1.25 GHz), X-band (10 GHz), and Ku-band (12 GHz). The required bandwidth varies from a few megahertz to 20 MHz to 300 MHz to achieve the desired resolution; the larger the bandwidth, the higher the resolution. Ocean altimeters and scatterometers typically operate at L-band (1.2 GHz), C-band (5.3 GHz), and Ku-band (12 GHz). Ka-band (35 GHz) interferometers have applications to river discharge. The atmospheric radars operate at very high frequencies (35 GHz and 94 GHz) with only modest bandwidth requirements on the order of a few megahertz.

The emphasis of this subtopic is on core technologies that will significantly reduce mission cost and increase performance and utility of future radar systems. There are specific areas in which advances are needed.
• SAR for surface deformation, topography, soil moisture measurements:
  
  - Very large aperture L-band antennas (20 m x 20 m) for Medium Earth Orbit (MEO) or 30m diameter for Geosynchronous SAR applications.
  - Shared aperture, multi-frequency antennas (P/L-band, L/X-band).
  - Lightweight, deployable antenna structures and deployment mechanisms.
  - Rad-hard, high-efficiency, high power, low-cost, lightweight L-band and P-band T/R modules.
  - High-power transmitters (L-band, 50-100 kW).
  - L-band and P-band MMIC single-chip T/R module.
  - Rad-hard, high-power, low-loss RF switches, filters, and phase shifters.
  - Digital true-time delay (TTD) components.
  - Thin-film membrane compatible electronics. This includes: reliable integration of electronics with the membrane, high performance (>1.2 GHz) transistor fabrication on flex material including identifying new materials, process development, and techniques that have the potential to produce large-area passive and active flexible antenna arrays.
  - Advanced transmit and receive module architectures such as optically-fed T/R modules, signal up/down conversion within the module, and novel RF and DC signal distribution techniques.
  - Advanced radar system architectures including flexible, broadband signal generation and direct digital conversion radar systems.
  - Advanced antenna array architectures including scalable, reconfigurable, and autonomous antennas; sparse arrays; and phase correction techniques.
  - Distributed digital beamforming and onboard processing technologies.

• SAR data processing algorithms and data reduction techniques.
• SAR data applications and post-processing techniques.

• Low-frequency SAR for subcanopy and subsurface applications:
  
  - Lightweight, large-aperture (30 m diameter) reflector and reflectarray antennas.
  - Large, electronically scanning P-band arrays.
  - Shared aperture, dual-polarized, multiple low-frequency (VHF through P-band, 50-500 MHz) antennas with highly shaped beams.
  - Lightweight, low frequency, low-loss antenna feeds (VHF through P-band, 50-500 MHz).
  - High-efficiency T/R modules and transmitters (50-500 MHz, 10 kW).
  - Lightweight, deployable antenna structures and deployment mechanisms.
Data applications and post-processing techniques.

- **Polarimetric ocean/land scatterometer:**
  - Multi-frequency (L/Ku-band) lightweight, deployable reflectors.
  - Large, lightweight, electronically steerable Ku-band reflectarrays.
  - Lightweight L-band and Ku-band antenna feeds.
  - Dual-polarized antennas with high polarization isolation.
  - Lightweight, deployable antenna structures and deployment mechanisms.
  - High efficiency, high power, phase stable L-band and Ku-band transmitters.
  - Low-power, highly integrated radar components.
  - Calibration techniques, data processing algorithms, and data reduction techniques.
  - Data applications and post-processing techniques.

- **Wide swath ocean and surface water monitoring altimeters:**
  - Shared aperture, multi-frequency (C/Ku-band) antennas.
  - Large, lightweight antenna reflectors and reflectarrays.
  - Lightweight C-band and Ku-band antenna feeds.
  - Lightweight, deployable antenna structures and deployment mechanisms.
  - High-efficiency, high power (1-10 kW) C-band and Ku-band transmitters.
  - Real-time onboard radar data processing.
  - Calibration techniques, data processing algorithms, and data reduction techniques.

- **Ku-band and Ka-band interferometers for snow cover measurement over land (Ku-band), wetland, and river monitoring (Ka-band):**
  - Large, stable, lightweight, deployable structures (10-50 m interferometric baseline).
  - Ka-band along and across-track track interferometers with a few centimeters of height accuracy.
  - Ku-band interferometric polarimetric SAR.
  - Phase-stable Ku-band and Ka-band electronically steered arrays and multibeam antennas.
  - Lightweight deployable reflectors (Ku-band and Ka-band).
  - Shared aperture technologies (L/Ku-band).
Phase-stable, Ku-band and Ka-band receive electronics.

High-efficiency, rad-hard Ku-band and Ka-band T/R modules or >10 kW transmitters.

Ku-band and Ka-band antenna feeds.

Calibration and metrology for accurate baseline knowledge.

Real-time onboard radar data processing.

Data applications and post-processing techniques.

- **Atmospheric radar:**

  - Low sidelobe, electronically steerable, millimeter wave, phased-array antennas and feed networks.
  
  - Low sidelobe, multi-frequency, multi-beam, shared aperture millimeter wave antennas (Ka-band and W-band).
  
  - Large (~300 wavelength), lightweight, low sidelobe, millimeter wave (Ka-band and W-band) antenna reflectors and reflectarrays.
  
  - Lightweight deployable antenna structures and deployment mechanisms.
  
  - High power (10 kW) Ka-band and W-band transmitters.
  
  - High-power (>1 kW, duty cycle >5%), wide bandwidth (>10%) Ka-band amplifiers.
  
  - High-efficiency, low-cost, lightweight Ka-band and W-band transmit/receive modules.
  
  - Advanced transmit/receive module concepts such as optically-fed T/R modules.
  
  - Onboard (real-time) pulse compression and image processing hardware and/or software.
  
  - Advanced data processing techniques for real-time rain cell tracking, and rapid 3D rain mapping.
  
  - Lightweight, low-cost, Ku/Ka band radar system for ground-based rain measurements.
  
  - Light weight, wideband (>200 MHz), low-sidelobe (large)
  
  - Low-power, high-speed, multi-channel single board digital receivers.
  
  - High-power, high-duty cycle solid state power amplifier from X through W-band.