NASA Program Plans for Sub-millimeter Wave Astronomy

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Outline of Presentation

Astrophysics Division

- NASA's Astrophysics Program
- Planned Missions
- Technology Requirements for Future Missions
- Comments and Summary

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Program Goal

Astrophysics Division

Conduct a comprehensive exploration of the universe

Themes:

- Astronomy: What is the nature of planets, stars and galaxies?

- Cosmology: What is the origin and fate of the universe?

- Physics: What are the laws of physics in the extreme conditions of astrophysical objects?

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Program Strategy

Astrophysics Division

- Contemporaneous observations across the electromagnetic spectrum with high sensitivity, high angular resolution and high spectral resolution

  - *Implemented through the Great Observatories*

- Fill in crucial gaps in "wavelength" or "spectroscopy" space

  - *Implemented through Explorers and moderate missions*

- Maintain National science and technology capability

  - *Implemented through grants, sub-orbital program and technology development*

- Analyze and publish results

  - *Implemented through Mission Operations and Data Analysis program*

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Science Planning Process

Astrophysics Division

- Strong grass roots community involvement in our program
  - Four Management Operations Working Groups (MOWGs) plus "Astrophysics Council"
- National Academy of Sciences
  - Committee on "Space Astronomy and Astrophysics"
  - 10 year strategy from "Bahcall report" to be released March 19, 1991
  - Prioritizes all National astronomy programs
- Integrate astrophysics initiatives into OSSA program plan

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Great Observatories

Astrophysics Division

- Hubble Space Telescope (HST)
- Gamma Ray Observatory (GRO)
- Advanced X-ray Astrophysics Facility (AXAF)
- Space Infrared Telescope Facility (SIRTF)

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Sub-millimeter Astronomy Missions

Astrophysics Division

- Kuiper Airborne Observatory (KAO)
- Sub-millimeter Wave Astronomy Satellite (SWAS)
- Stratospheric Observatory for Infrared Astronomy (SOFIA)
- Sub-millimeter Moderate Mission (SMMM)
- Large Deployable Reflector (LDR)
- Sub-millimeter Interferometer

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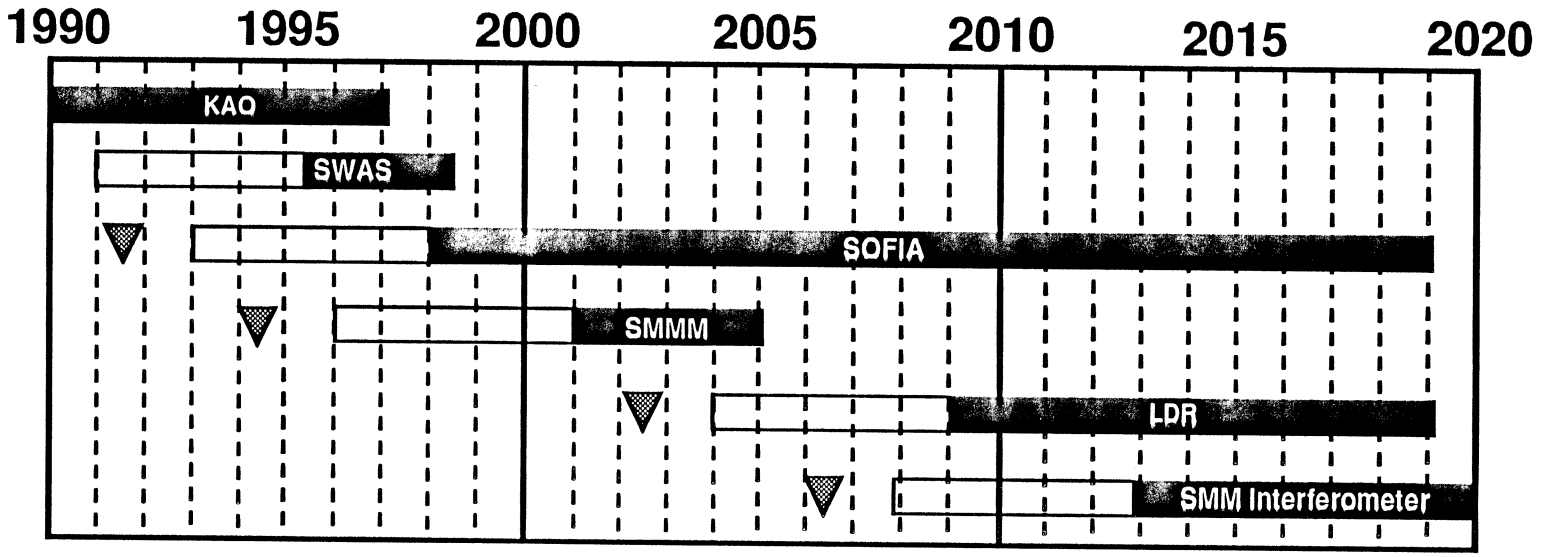
Sub-millimeter Astronomy Program Plans

Astrophysics Division



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Sub-millimeter Wave Astronomy Satellite (SWAS)

Astrophysics Division

- Science Strategy: SWAS will perform both pointed and survey observations in 4 lines crucial to the study of interstellar cloud chemistry, energy balance and structure: 487, 557, 492 and 551 GHz
- Description:
  - 3 axis stabilized, stellar-pointing "Small Explorer" spacecraft (Scout-class)
  - 530 km altitude, 3 degree inclination angle orbit
  - 55 cm off-axis Cassegrain antenna, passively cooled heterodyne receivers and acousto-optical spectrometer
- Launch Date: 1995
- Principal Investigator/ Payload List:
  - PI -- Dr. Gary Melnick, SAO
  - Antenna, Star Tracker, Instrument Integration -- Ball Aerospace
  - Sub-millimeter Heterodyne Receiver -- Millitech
  - Acousto-optical Spectrometer -- University of Cologne
- NASA Program Manager: Dr. David Gilman, NASA HQ

Stratospheric Observatory for Infrared Astronomy (SOFIA)

- Science Strategy: SOFIA will provide frequent, high-quality access to the IR/sub-mm spectral region
- Description:
  - 2.5 m Nasmyth IR telescope housed in a modified Boeing 747 SP aircraft
  - Operates from 0.3 to 1600 microns
  - Sensitivity ~ 10^{-19} W/cm^2 /SR
  - Angular Resolution: 2 arcsec in near IR and diffraction limited at wavelengths > 30 microns
  - 120 flights/year with 30 - 40 research teams/year
- Launch Date: 1998
- Technology Development Requirements:
  - Lightweight f/1 primary mirror (Zeiss)
  - Shear layer control
  - Large air bearing
- NASA Program/Project Manager: Mike Kaplan, NASA-HQ / Dr. Gary Thorley, NASA-ARC

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Sub-millimeter Moderate Mission (SMMM)

Astrophysics Division

- Science Strategy: SMMM will be a spectral survey of selected objects from 100 - 750 microns and imaging in the 100 - 300 micron range
- Description:
  - 2.5 to 4 m segmented, ambient temperature aperture
  - High orbit, 2 year lifetime
  - Liquid He-cooled focal plane
    - -- Fabry-Perot spectrometer with 0.1 deg K bolometers
    - -- IR camera with 0.3 deg K bolometers
    - -- Ten-band heterodyne radiometer operating at 2 deg K
- Mission Options: Explorer-class (2.5 m aperture, spectroscopy only), CNES and/or ESA collaboration
- Launch Date: 2001 ?
- Technology Development Requirements:
  - SIS mixers, heterodyne receivers with sensitivities within a factor of 5 of the quantum limit and local oscillators with increased conversion efficiency
  - Far IR integrating arrays (impurity band conduction technology)
  - Bolometers
  - Lightweight precision aperture
- Science Working Group Chairman: Dr. Tom Phillips, Caltech

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Large Deployable Reflector (LDR)

Astrophysics Division

- Science Strategy: LDR will view sources in the wavelength region between 30 and 3000 microns
- Description:
  - 20 m - class diameter antenna for imaging spectroscopy and photometry composed of 90 lightweight, hexagonal panels, 4 mirror, two-stage optical system
  - Diffraction limit < 50 microns
  - Spectral resolving limit from 10 to 10^5
  - Angular resolution of 1 arcsec at 100 microns
  - Sensitivity > 2 x 10^{-14} W/cm^2/SR
- Launch Date: 2009 ??
- Technology Development Requirements:
  - Lightweight mirror segments
  - Active figure control
  - Heterodyne receivers with SIS mixers
  - Long lifetime cryogenics
- NASA POC: Dr. Larry Caroff, NASA-HQ

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Sub-millimeter Interferometer (SMMI)

Astrophysics Division

- Science Strategy: SMMI will view sources in the wavelength region between 30 and 1000 microns with 100x better resolution than any other existing or proposed instrument. Based at lunar outpost
- Description:
  - Two-dimensional array of 5 - meter antennas distributed on baselines from 50 m to several km
  - Actively-cooled, superheterodyne receivers
  - Spectral resolving limit from 10 to 10^6 over the entire spectrum 10 GHz BW
  - Angular resolution of 10 milliarcsec at 100 microns
- Launch Date: 2013 ??
- Technology Development Requirements:
  - High throughput correlators
  - Lightweight materials that operate at 100 deg K and cycle to 385 deg K
  - Fiber-optics
  - Telerobotic operation
- NASA POC: Mike Kaplan, NASA-HQ

Sample Mission Schedule for Major Astrophysics Space Observatory

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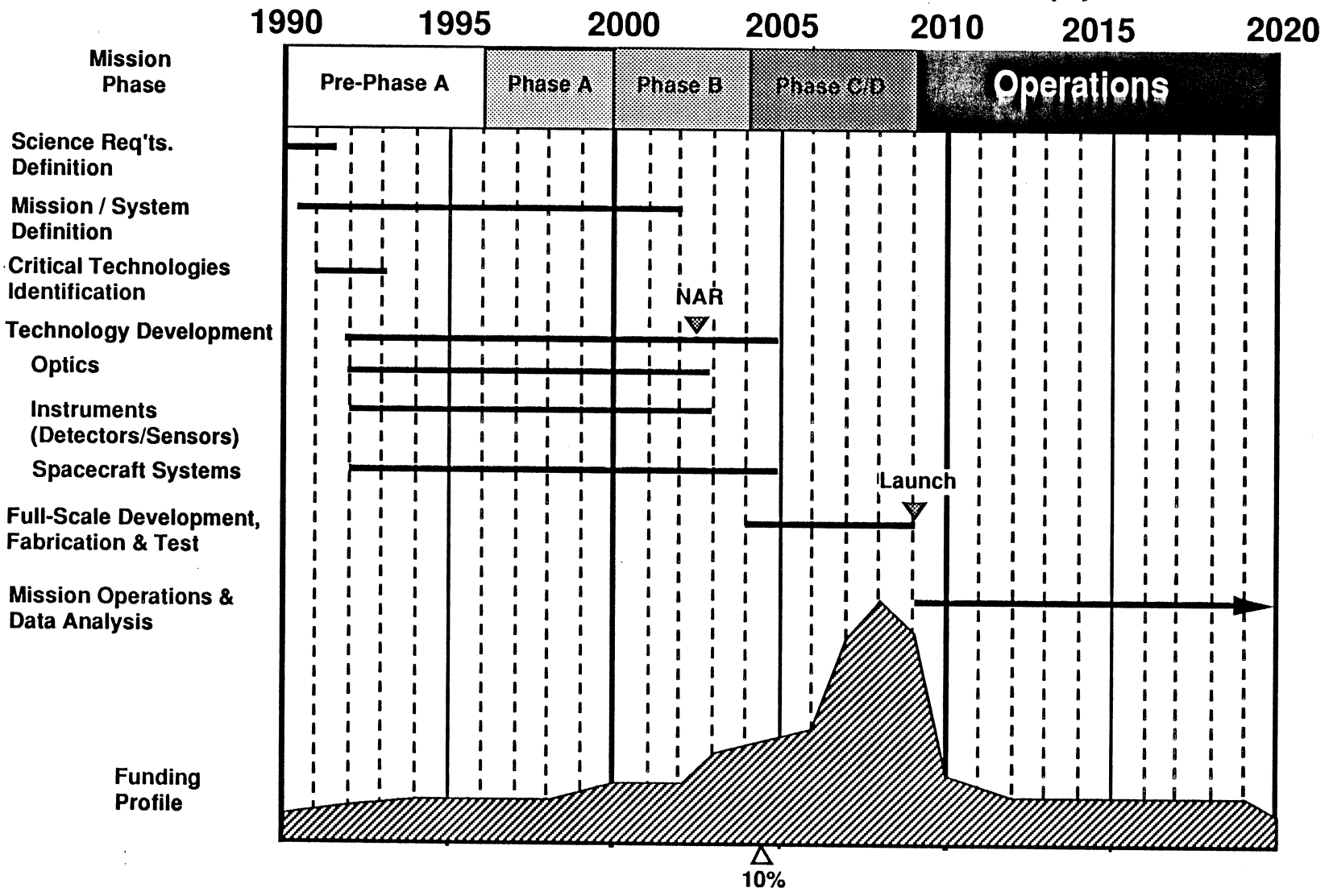

Technology Requirements for Sub-millimeter Astronomy Missions

- **Sub-millimeter Heterodyne Receivers**: Develop robust, space-qualifiable heterodyne technology for extension into the terraherhz regime, increased sensitivity and array applications

  - Local oscillator power of 50 microwatts to 20 mW for 200 GHz to 1 THz

  - Mixers with noise performance < 10 x quantum limit @ > 600 GHz to 3 THz

  - Low power, smaller size, larger bandwidth spectrometer concepts for space

  - Focal plane arrays covering 100 GHz to 2 THz

- **Sub-millimeter Apertures**: Develop large, precise lightweight segmented apertures up to 30 m in diameter with excellent thermal characteristics - NASA OAET Precision Segmented Reflector (PSR) program

- **Others**:

  - Space cooler and cryogenic technology - to support long duration missions

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Comments & Summary

Astrophysics Division

- Release of Augustine report has caused new emphasis on space science within NASA
- We will see a revolution in space astronomy over the next decade
- NASA has ambitious plans to explore the universe in sub-millimeter portion of the electromagnetic spectrum
- These missions are **enabled** with the development of new sub-millimeter wave technology
- Exciting times for sub-millimeter wave astronomy are around the corner!!