A Simple Tool for Design and Analysis of Multiple-Reflector Antennas in a Multi-Disciplinary Environment

JPL

Tom Cwik, D. Katz, A. Borgioli, C. Fu, W. Imbriale, V. Jamnejad, P. Springer*
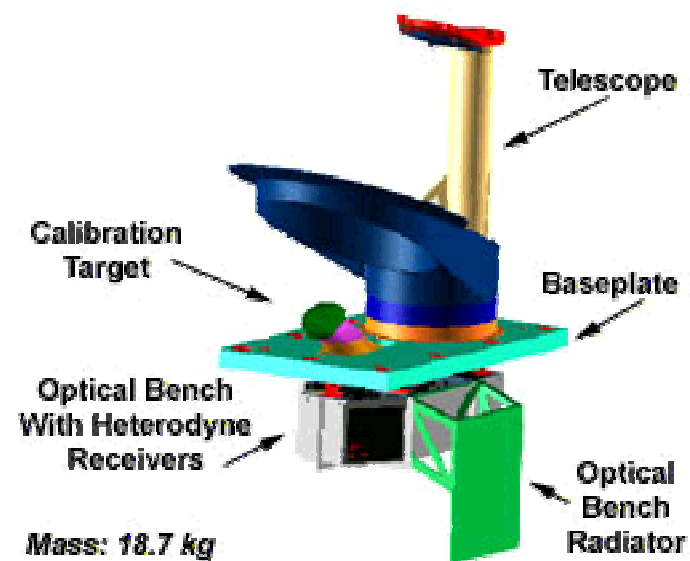*Jet Propulsion Laboratory*
*University of California at Santa Barbara

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IEEE AP-S , Orlando FL

MOTIVATION

✳ For the foreseeable future, JPL is proposing, designing and building microwave and millimeter wave instruments

✳ Instruments meet design criteria obtained from science mission goals

- Beamwidth, sidelobes
- Pointing
- Gain

✳ Design criteria are functions of space environment

- Fluctuating thermal (deep space and earth orbiting)
- Mechanical due to thermal load

✳ Software design tools and environments maturing and becoming integrated

Telescope

Calibration Target

Baseplate

Optical Bench With Heterodyne Receivers

Optical Bench Radiator

Mass: 18.7 kg

MIRO Instrument (JPL)
wwwmiro.jpl.nasa.gov

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## Current Design Tools and Process

✳ Disciplines/Tools:
- CAD
  Pro/Engineer
  CV
  IDEAS
- Meshing
  FEMAP
- Structural
  NASTRAN
- Thermal
  TRASYS
  SINDA
- Antenna/Optics
  MACOS
  POPO

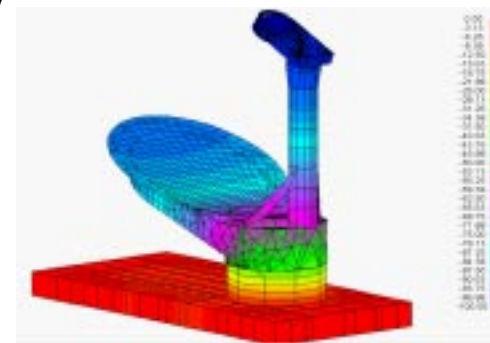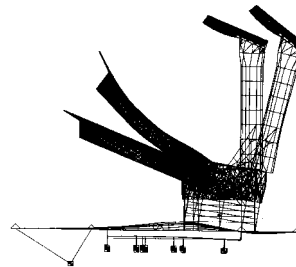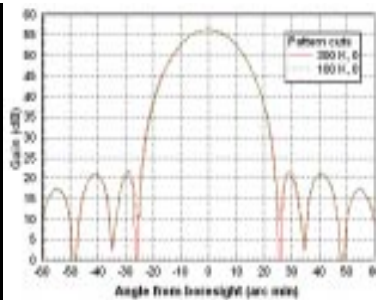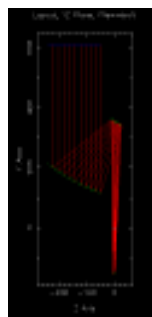✳ Each tool is used by an analyst/designer, who works in one discipline

✳ When one analyst completes a model, it is passed to the next

✳ <u>This work focuses on antenna electromagnetic design, and how it is connected to the other disciplines through a common digital geometry</u>

MODTool (Millimeter-wave Optics Design Tool)
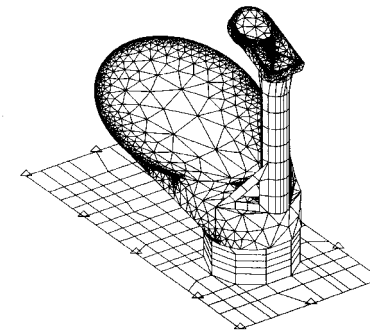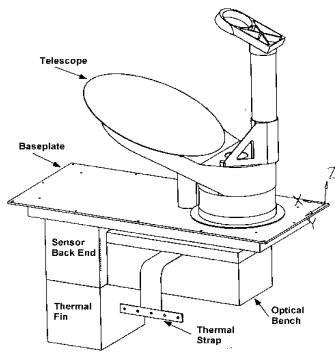
Common Geometry

MODTool Goals

✻ Develop new code only if necessary

- Try to use/reuse:

  Commercial applications

  Previously developed JPL applications

- Try to develop code so that it can be used for other future projects

  Use standard packages/tools

  Always think beyond this project

✻ Ensure users on multiple platforms can easily use tool (client-server)

- Client written in Tcl/Tk

  Freely available over the web

  Available for Unix, PC, Mac

- Server also written in Tcl/Tk, but on a specific type of machine

  Uses compiled C code using Unix libraries for user authentication

COMMON GEOMETRY

✴ Much of the underlying effort was spent in defining a common geometry that can be used by structures, thermal and electromagnetic design

- Thermal: 100s of mesh points (degrees of freedom)

- Structures: 1000s of mesh points

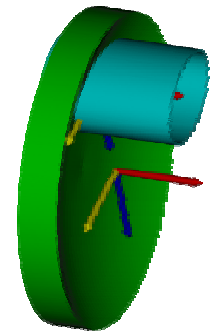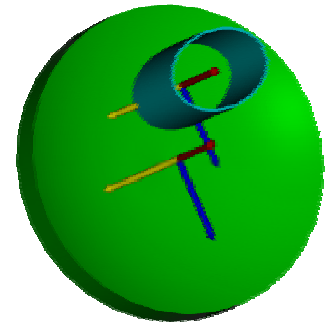- Electromagnetic: 10,000s of mesh points

✴ A common analytic description of the antenna surfaces was defined, and any distortions produced from structural/thermal analysis codes were interpolated and added to analytic description

- Struts, backup structure, spacecraft structures models used in structural/thermal analysis; data stripped for use with electromagnetic analysis

Interface and Functionality

✳ Designer starts client code on designer's machine (The Application Interface)

- Designer must enter username and password

- Designer must select existing or new project on which to work

✳ Client opens socket to server (Automatic and Invisible)

- Server validates username and password

- Server creates local work directory

✳ Designer may then work in one of six modes:

- Design

- Prescription

- Geometric Optics Analysis

- Physical Optics Analysis

- Submitting a Mesh

- Submitting a Load

Interface to thermal and structural design

Design Mode

✴ Allows designer to create or modify a design

✴ A design is the description of a set of antenna elements

- Conic sections:

  paraboloids, hyperboloids, ellipsoids, flat plates, all cut by an elliptical cutting cylinder

- Feed location and output coordinate system definitions

✴ The elements are shown graphically, and the values which control the elements are shown as a table

- Either the data in the table or the graphical data may be varied

- The two displays are linked - changes in one are reflected in the other

Design Mode (Cont'd)

Prescription Mode

✳ Allows the user to create or modify a prescription

✳ A prescription is an ordered list of a subset of the optical elements from the design

- Determines which elements should be analyzed and in what order
- Needed because instruments can have multiple "optical" paths

  Instrument will be used at multiple frequencies

  Instrument has multiple modes of operation

✳ Elements may be modified in location or orientation from the base elements as stored in the design

- Used for tolerancing analysis

Prescription Mode (Cont'd)

GO Analysis Mode

✶ Allows the user to perform geometric optics analysis on a design and prescription

✶ These files are converted to a MACOS input set

- MACOS provides computationally efficient general ray-trace, differential ray-trace, and scalar-diffraction calculation capabilities
- Developed at JPL, starting in 1989
- Commercial and U.S. Government versions are available

✶ The files must be on the server, which does the conversion, and runs MACOS

- Only the general ray-tracing capabilities of MACOS are currently supported through MODTool

GO Analysis Mode (Cont'd)

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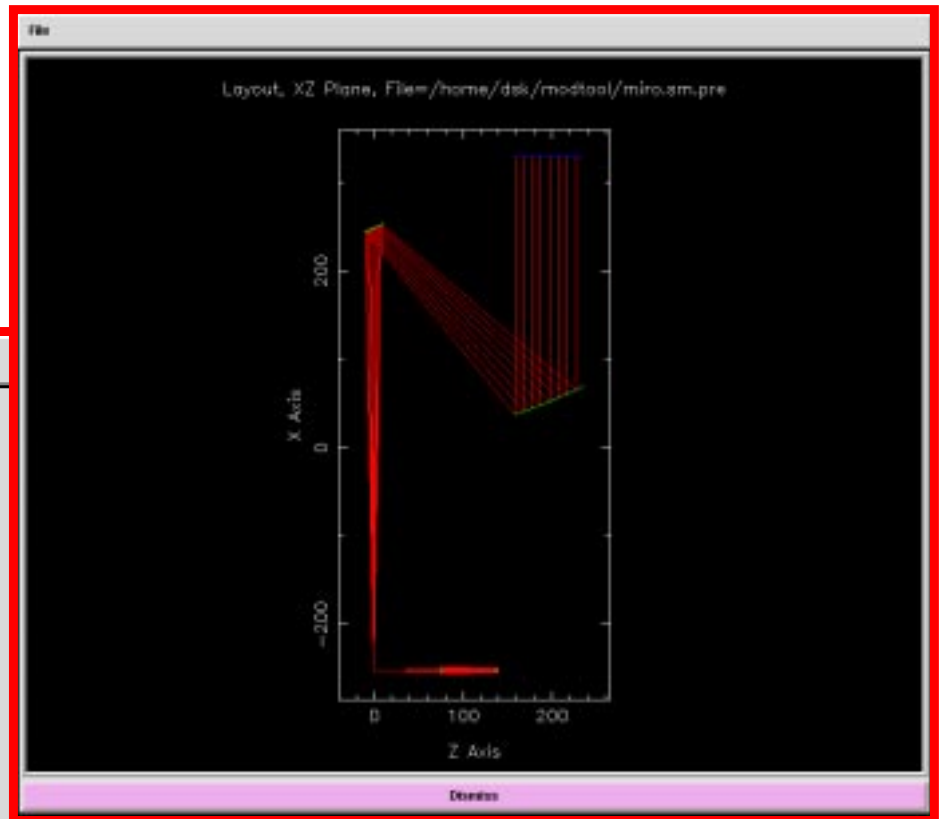
Physical Optics Mode

✳ Physical Optics (POPO) code

- Developed at JPL over a long period of time (1971 - present)

- Versions exist for PCs, workstations, Cray J90, T3D, Beowulf

✳ Can analyze surfaces from design and prescription mode

✳ Can also add deformations from load file before analyzing

- Done using MATLAB to read mesh and load data, and to calculate coefficients for a bipolynomial (or other) surface approximating the deformation

- MATLAB is run on the server, where the design, prescription, mesh and load files are stored

✳ POPO code is run on supercomputers

- Using username and password for that machine supplied by user

- Ensures correct accounting and time-charging

- Expect is used between the server and the supercomputer

PO Mode (Cont'd)

Mesh and Loads

✳ Used by structural, thermal and electromagnetic engineers

✳ Submits a mesh of an instrument from a client to the server

- Currently, meshes must be FEMAP neutral files
- One layer is used for the elements that make up each optical element

✳ Validates that mesh and the "analytic" design are the same geometry

✳ Used with the load data for physical optics analysis of loaded instruments

✳ Deformations come from structural or thermal loads

- How the instrument will change from the original design when it is in its operating environment

✳ The load data must be logically tied to a set of mesh data

✳ This data is used in the physical optics analysis, with the corresponding mesh data

✴ <u>Adding ZEMAXS 3D optical software as addition to Design input mode</u>

✴ <u>Interfacing to tool set in JPL TEAM I (Instrument) a concurrent engineering center</u>

Ocean-Salinity Soil-Moisture Integrated Radiometer-Radar Imaging System
(OSIRIS) E. Njoku-JPL (Proposal)