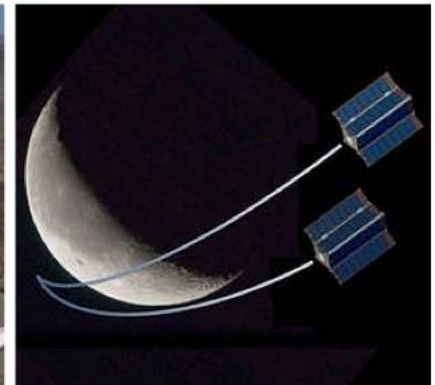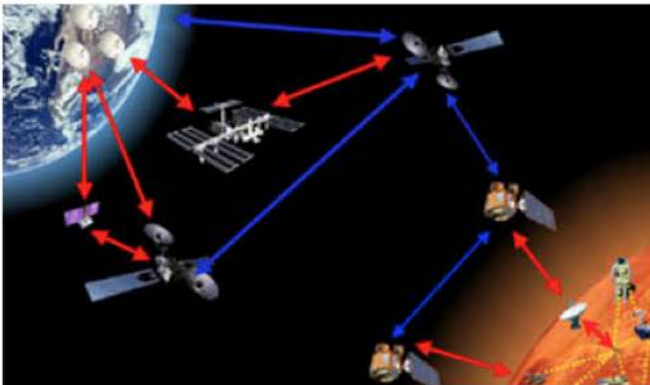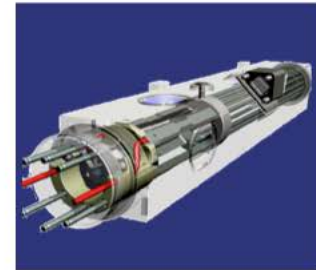# How DSN Technology Changed the World

Laif Swanson
JPL Communications Architectures & Research Section

DSN Technology

- **The DSN (and its predecessors) developed enormous capability**

  – **Active technology program**

  – **Excellent engineering**

- **Of course it has brought us planetary science**

  – **Pictures have become ubiquitous and almost unremarkable**

  – **But the technology developments have brought the world much more**

- **Technology developed by & for the DSN often based on others**

  – **Often radio astronomy**

  – **We usually know about this**

  – **When other entities use our technology, we may not know**

 – **These examples come from the people who have worked on them**

Goldstone Solar System Radar

- **Goldstone Solar System Radar is both a beneficiary and a benefactor**

  - **Has imaged many solar system objects**

  - **Advanced our knowledge of AU by two orders of magnitude**

  - **Determined good spacecraft landing sites on moon and Mars**

  - **Located SOHO when it lost lock on sun, saving mission**

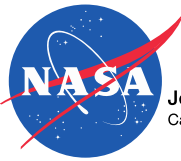 - **Served as a testing ground for new technology**

2005 YU55
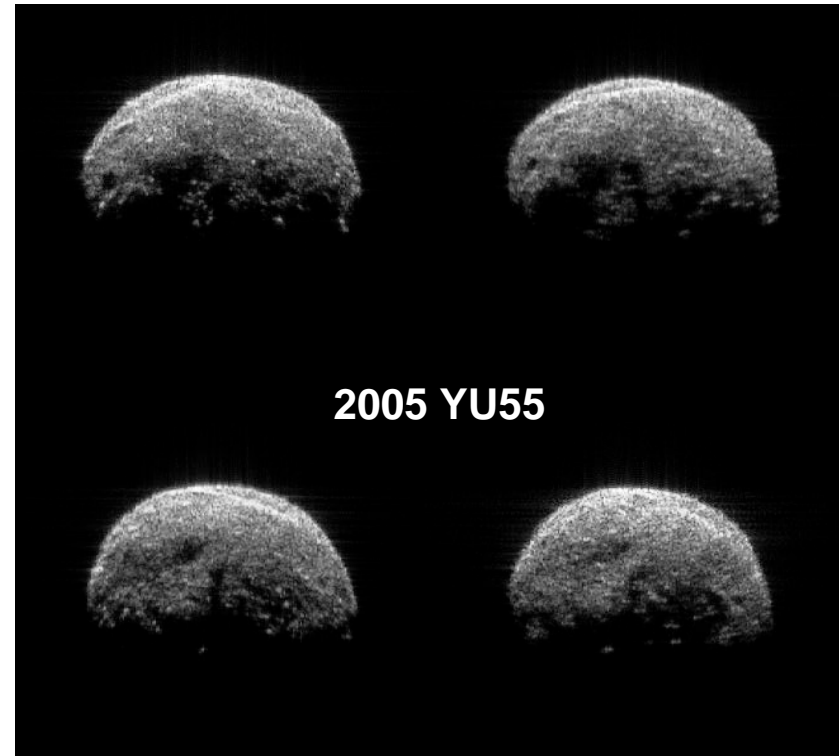
Ways Others use DSN Technology

- **Radio astronomy and ground stations for other agencies' space programs**

  - **This is the most obvious, since we have been first so often**

- **Spacecraft technology**

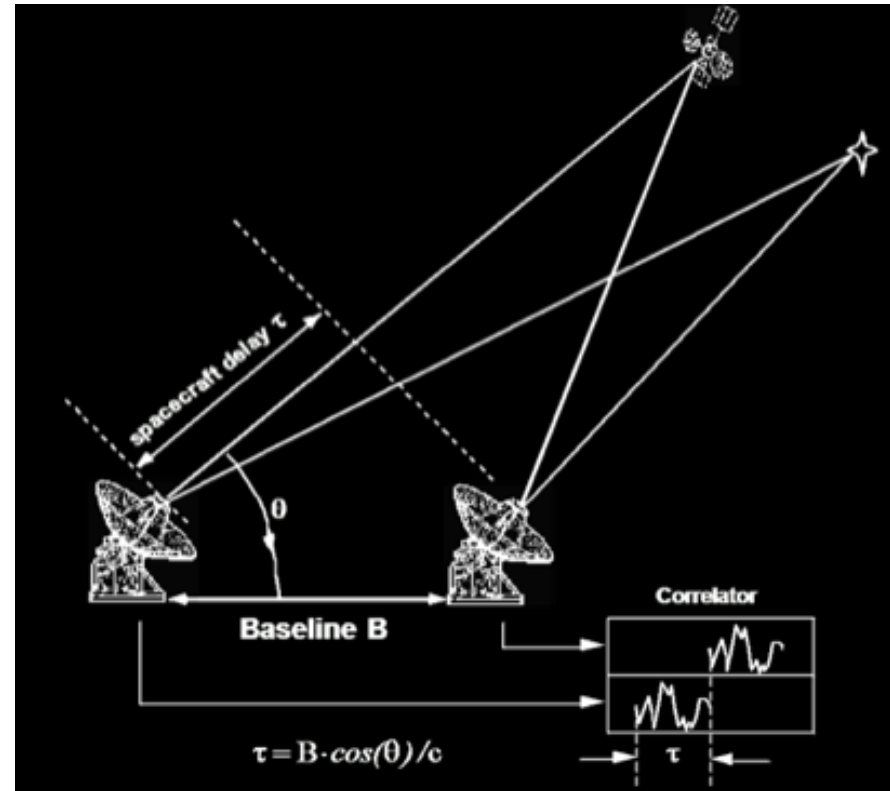- **The outside world**

Radio Astronomy & Ground Stations

- **VLBI**

  - **First developed for radio astronomy**

  - **DSN capability allowed collaboration**

  - **DSN developed delta DOR**

  - **Now used widely by other space agencies**

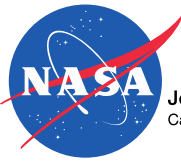# Low Noise Amplifiers

- **Compact cryogenically cooled choked waveguide for low-noise input coupling into cryogenically cooled amplifier used by**
  - **Radio astronomers**
  - **SETI**
  - **ESA**
  - **CSIRO**
  - **DFVLR**

- **Reflected-Wave Maser developed in early 70s used by**
  - **NRAO**
  - **VLA**
  - **CSIRO**
  - **Max Planck**
  - **Caltech**
  - **Princeton**

X-Band "ULNA"

Low Noise Amplifiers (continued)

Jet Propulsion Laboratory
California Institute of Technology

- **Cryogenically cooled traveling masers and closed-cycle refrigerator systems**
  - **Developed in the early 1960s and late 1970s**
  - **Later used at Arecibo**

More Ground Station Adoptions

- **Beam waveguide antennas**

  - **Originally developed by the Japanese**

  - **We developed**

    - **Wideband**

    - **High-efficiency**

    - **Low noise**

    - **Electronic system below ground for ease of access and station electronic stability**

  - **Largely adopted by ESA and more recently Indian Space Research Organization**
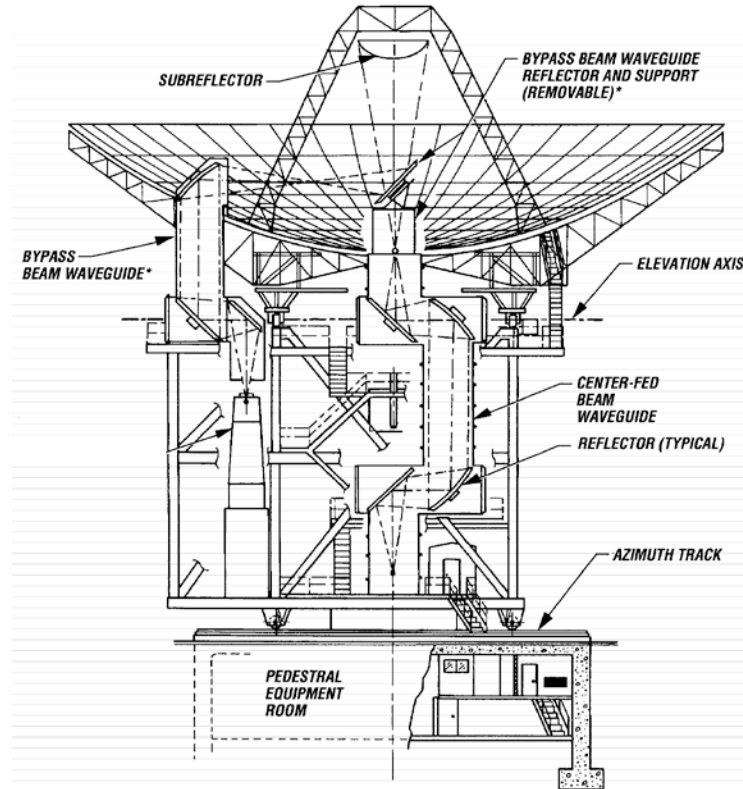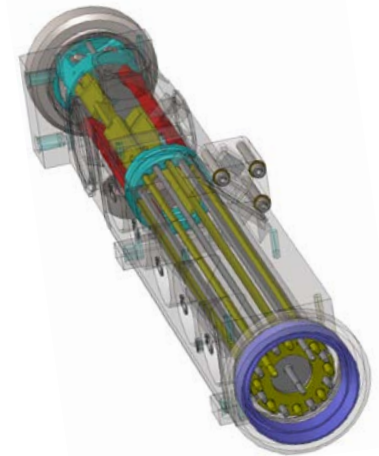
Technology Adopted by Spacecraft

- **Radar Interferometry**

  - **NASA aircraft**

  - **SIR-A, SIR-C**

  - **ESA used on ERS1, ERS2, EnviSat**

- **Ferrite circulator as part of system to phase lock existing high-power Ka-band oscillator**

  - **In lieu of high-power amplifier**

  - **Being considered for use by Cloudsat**

- **Mercury Ion Frequency Standard**

  - **Being supported by NASA for spacecraft applications**

Deep Space Atomic Clock

Data Compression Used by Spacecraft

- **The Rice Algorithm**
  - **"Lossless" compression**
  - **Developed by the Voyager Mission**
  - **Used by DSN Technology program as the beginning of data compression work**

- **Galileo S-band mission**

  - **Finally spacecraft teams took lossy data compression seriously**

- **"Icer" algorithm**

  - **Developed by DSN technology program to ease data volume**

  - **Used on spacecraft for compression of thousands of images**

    - **Mars Exploration Rover**

    - **Mars Science Laboratory**

    - **Solar Terrestrial Relations Observatory (STEREO)**

DSN Technology Used Elsewhere

- **Phased Locked Loop**

  - **Invented elsewhere in the 30s**

  - **A great deal of research at JPL in the 1950's**

    - **Customized for new applications**

    - **Theory developed**

  - **Now used in space communications and**

    - **Frequency synthesis**

    - **Carrier synchronization**

    - **PN code synchronization**

    - **Bit synchronization**

  - **There are several in your smart phone**

Other Uses of DSN Technology

- **Pseudo-Noise (PN) codes**

  – **First used for radio guidance systems for missiles**

  – **Later used for planetary radar and ranging**

  – **Now used in**

    - **GPS**

    - **CDMA**

      – **Military Communications**

      – **Cell phones**

    - **Radar ranging**

- **Two-way phase-coherent Doppler**

  – **Developed for early missile guidance**

 – **Then radar speed guns**

Frequency Standards

- **Cryogenic oscillator**

  – **Developed for radio science**

  – **Used worldwide in national meteorological labs**

- **Opto-electronic oscillators**

  – **Based on JPL's Gallery Mode Oscillator**

  – **Adopted by DoD and flown in missiles**

  – **Commercialized and being pursued many places**

Fiber-Optic Frequency Distribution

- **Developed for the DSN**

- **First fiber-optic system in space (SRTM)**

- **Basis for fiber-optic based cable TV**

- **Basis for distribution of optical frequency standards in Europe and Asia**

- **Being developed for same use in U.S.**
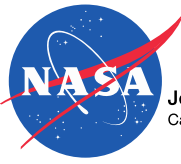
Error-Correcting Codes

- **Early coding was largely a mathematical curiosity**

- **DSN was very early user of digital communications**

- **Distance and spacecraft amplifier power lead to very low signal-to-noise ratio (even after those low-noise amplifier people made the noise very small)**

- **Reed-Solomon code concatenated with convolutional code and Viterbi decoding**
    - **None of these things came from JPL**
    - **This particular code began with Voyager 2**
    - **Very popular for a lot of purposes**
    - **First generation DVB-S digital television broadcast standard**
    - **(7,1/2) convolutional code with Viterbi decoding ubiquitous in communications**
    - **Reed-Solomon codes ubiquitous in data storage**
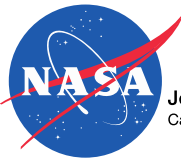
Turbo Codes and LDPC Codes

- **These were invented elsewhere**

- **Specific codes developed in the DSN Technology program are now available commercially**

- **3G and 4G cellular standards use these types of (though not exactly these) codes**

- **"Protograph LDPC codes" enable low-complexity encoders and decoders**

Other Developments

- **Computer tomography can be traced to VLBI**

- **DSN VLBI led to the crustal dynamics program**

- **Shazam has roots in stellar navigation**

- **Chemical degradation in the pedestal of DSS-14 led to solutions that were then used to refurbish highways**

- **And even now – Superconducting nanowire single photon detector recently developed for the DSN is being explored in labs around the world in quantum optics and spectroscopy experiments**
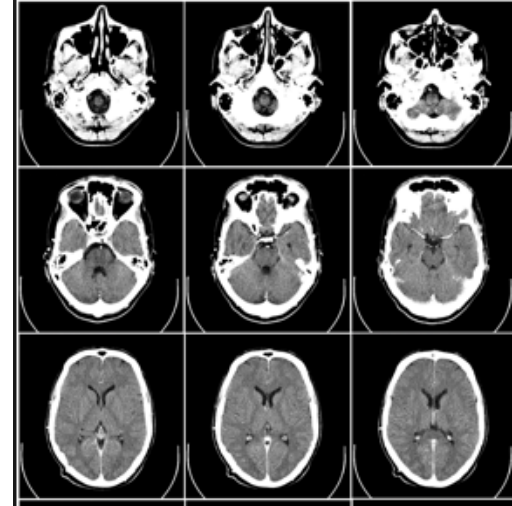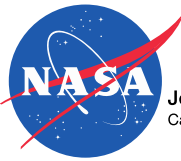
Some other thoughts

With Thanks To

- **Dimitri Antsos**
- **Dan Bathker**
- **Jim Border**
- **Bob Clauss**
- **Les Deutsch**
- **Bill Farr**
- **Rick Green**
- **Jon Hamkins**
- **Dan Hoppe**
- **Aaron Kiely**
- **Pete Kinman**

- **Lute Maleki**
- **Francesco Marsili**
- **Dick Mathison**
- **Doug Mudgway**
- **Mac Reid**
- **Michael Rodrigues**
- **Matthew Shaw**
- **Marty Slade**
- **Charles Stelzried**
- **Lincoln Wood**
- **Joe Yuen**