The Early History of Canadian Planetary Exploration

Kieran A. Carroll, Ph.D.

CASI 18th Astronautics Conference
16 May 2018

Overview

- The Canadian Space Agency currently funds planetary exploration activities, via its Space Exploration Branch
- Prior to 2000, this was not the case
- Before then, the Canadian government provided little support for planetary exploration
- Nonetheless, some Canadians were involved in various planetary exploration activities carried out by other countries, during that period
- “Pre-history” of Canadian planetary exploration
- Via a few stories I’ve gathered over the years
  - Some perhaps not known to many

Planetary Exploration vis-à-vis Other Space Activities

- **CSA-Funded Planetary Exploration:**
  - *Exploration of planets other than the Earth, directly or indirectly*
  - Thermal Plasma Analyzer/Nozomi: Mars atmosphere
  - MOST: transiting exoplanets (planets around other stars)
  - NEOSSat: asteroid search and tracking
  - Mars Phoenix lidar weather station
  - Mars Curiosity Rover APXS instrument
  - OLA: OSIRIS-REx Laser Altimeter for asteroid exploration
- **Other CSA Space Activities:**
  - *Everything in Earth orbit*
  - Science satellites: Alouettes, Isis's, MOST, SciSat
  - GEO commsats, Radarsats
  - Canadarms, Astronauts on Space Shuttle and Space Station
  - Etc…

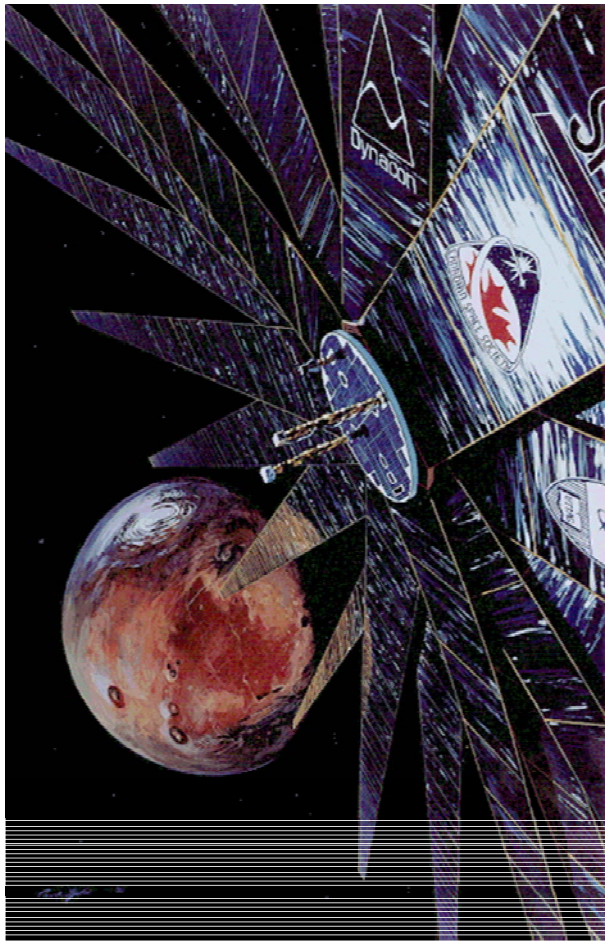
Why Am *I* Telling You About This?

- I've been promoting planetary exploration in Canada
  - Since long before it was fashionable ☺
- Co-founder of the Canadian Space Society in 1983
- Planetary exploration has long been a primary CSS goal
- Various group projects and activities related to this
- 1988/92: Canadian Solar Sail Project
- 1997/98: CSA LTSP-3 planetary exploration program proposal

- Also: I knew several of the people involved, and heard these stories from them
- Today I'll pass them along to you --- focusing on the people involved

Canadian Solar Sail Project

- Canadian entry into the CCQJC 1992 Solar Sail Race to Mars competition
- Amateur spacecraft design project
- 50-100 CSS volunteers worked on this over 4 years
- Goal: a spacecraft capable of reaching Mars distance from the Sun via solar sail propulsion
- Reached a preliminary design level, cost goal $20M
  - Didn't proceed to flight
- *AFAIK, nobody else in Canada was trying to do **any** planetary exploration during that era*
  - It was as if "the planets were off-limits for Canadians"
- **Led directly to the development of the first Canadian microsatellite mission, MOST**



Pre-2000 CSA Position on Planetary Exploration

- CSA budget had the following main Program lines:
  - Space Station
  - Radarsat-1, 2
  - Satellite Communications
  - Space Science
- The only one into which Planetary Exploration activities might fit was Space Science
- However, Space Science had only these 3 Program lines:
  - Space astronomy --- *only for stars, outside the Solar system!*
  - Upper atmosphere
  - Solar-terrestrial physics
- **The *only* part of space exploration CSA was *not* able to fund was exploration of the other planets in our Solar system!**

LTSP-3 Planetary Exploration Program Proposal

PROGRAM OVERVIEW TEMPLATE	**Program title:** Planetary Exploration Technology
Program element: Planetary exploration	
Related programs elements: Fundamental knowledge, Space operations, Robotics	
Timeframe (specific, relation to $ spent): ramp from $5M in fy1998 to $30M in fy2002; $30M/yr ongoing fy2003-fy2007	
Total program cost: $225M	
Program mission (user objectives): begin a visible role in international robotic planetary exploration	
Program components (project level): develop at least one substantial subsystem (e.g., a mini-rover) for international lunar-south-pole lander; develop technology to establish a significant Canadian role in future robotic planetary missions; prepare for possible Canadian contribution of small independent missions to future international planetary-exploration programs	
Rationale: To most people, planetary exploration is one of the most visible and most exciting aspects of spaceflight. Unlike communication satellites, scientific instruments, environmental research, etc., it is seen as directly contributing to the long-term dream of opening the skies to mankind: where robots go today, one day humans will follow. Specific long-term benefits of exploration may eventually appear but are difficult to predict; the immediate benefits of visible participation in planetary exploration are national pride, international prestige for our country and its industries, and public awareness and education. Canada's past participation in planetary exploration has been minimal. Achieving not just a role but a *visible* role requires that we supply not just components or services but an entire subsystem, preferably one that has some independence of operation, such as a manipulator arm or a mini-rover. Still better (but a longer-term prospect) would be to contribute a small independent *mission* as part of an international *program*, insulating us from partners' vagaries and giving us our own accomplishments to point to. Lunar and planetary exploration is resuming after a long hiatus. A modest investment now will give us the ability to participate at whatever level seems appropriate.	
Projected user community: space science (access to internationally-collected data); industry (other applications of exploration technology; prestige as marketing aid); Canadian public (national pride; educational inspiration)	
Technological objectives: miniature robotics; improved teleoperation and autonomous control; in-situ resources?; power beaming?	

Prior to that…

1959: The “NASA Canadians”

- Avro Arrow cancelled in March 1958
- In 1959, Canada “loaned” 25 of Avro’s top engineers to the new NASA’s Space Task Group, who were developing the Mercury spacecraft
- These were followed by 10 other engineers and doctors
- Most stayed working for NASA
- Many of these rose to senior roles in developing and operating and managing the Apollo spacecraft and missions to the Moon

Jim Chamberlin

- Avro Chief Aerodynamicist
- Chief of technical design for the Arrow
- Led the process of bringing the NASA Canadians down to work on the STG
- Became Head of Engineering for Project Mercury
- Project Manager for Project Gemini
- Trouble-shooter on Project Apollo

Owen Maynard

- Senior Stress Engineer on Avro Arrow
- Started at STG as a Project Engineer for first flight-test Mercury capsule
- In 1960, joined Advanced Vehicle Team, made initial sketches of what became the Apollo spacecraft
- 1963: Became Chief of LEM Engineering Office, led Lunar Module development
- 1964-69: Chief of Apollo Spacecraft Program Office Systems Engineering and Mission Operations Divisions

Early Apollo Design

- From “A Brief Introductory Description of Apollo”
- Presented by OEM, to the Lunar Sciences Sub-committee of the NASA Space Science Steering Committee
- Nov. 14-15, 1961
- Direct Ascent mission concept was then the baseline for Apollo

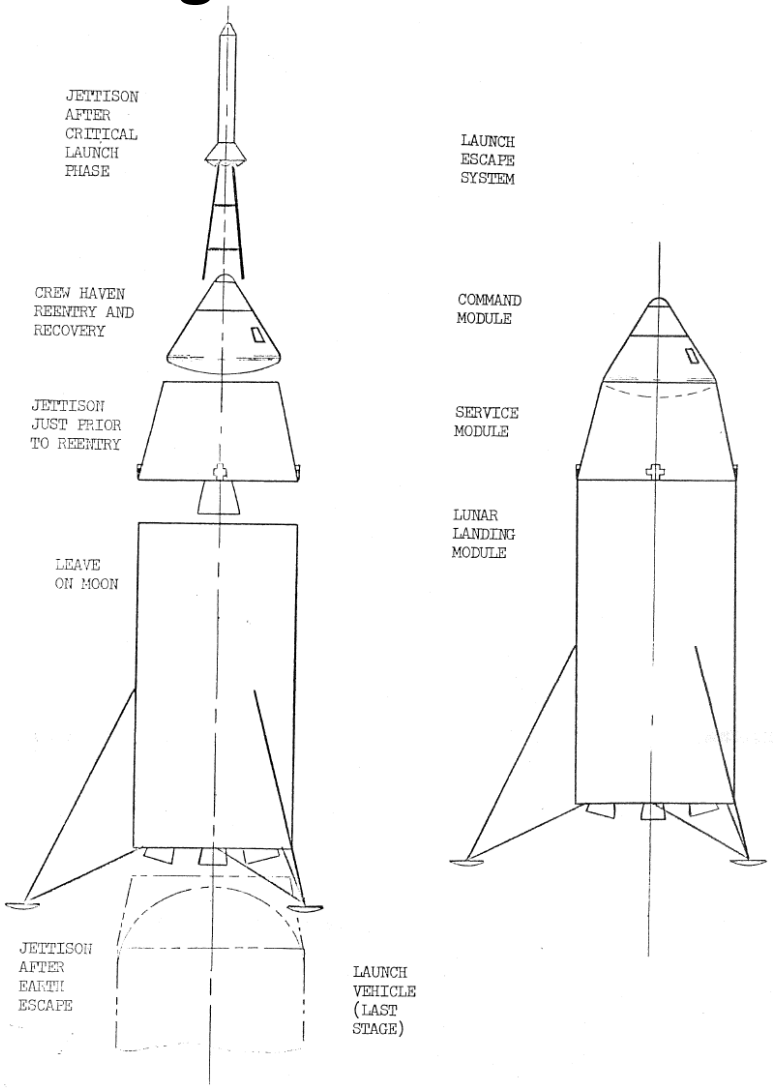
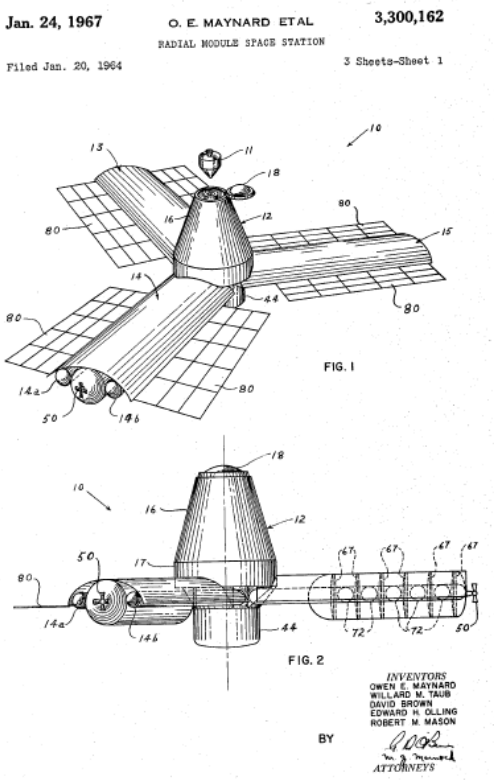
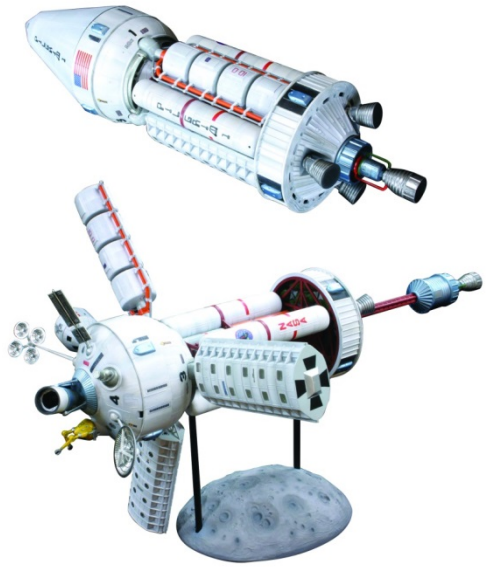


Figure 1.- Lunar landing modular arrangement.

“Radial Module Space Station”

- 1960: Advanced Vehicle Team developed concepts for a LEO space station, a manned Lunar mission, and a manned Mars mission
  - To be launched via NOVA
  - Propelled by NERVA
- This is the concept for the manned Mars mission
  - “What If” Kennedy had chosen Mars instead of the Moon?
- Later patented, became basis for a hobby plastic model kit!
  - MPC Pilgrim Observer


Jan. 24, 1967 O. E. MAYNARD ET AL 3,300,162
RADIAL MODULE SPACE STATION
Filed Jan. 20, 1964 3 Sheets-Sheet 1
FIG. 1
FIG. 2
INVENTORS
OWEN E. MAYNARD
WILLARD M. TAUB
DAVID BROWN
EDWARD H. OLLING
ROBERT M. MASON
BY
ATTORNEYS



More NASA Canadians

- **R. Bryan Erb:** Chief of Thermo-Structures Branch for Apollo spacecraft, led development of Lunar Receiving Lab
  - 1990s: Went on to manage CSA's ISS Office at JSC in Houston
- **John Hodge:** Flight Director
- **Rodney Rose:** Flight Operations planning
- **Tecwyn Roberts:** Mission Control designer, tracking system designer
- **Morris Jenkins:** Mission Analysis and Planning, designed Apollo Lunar trajectories





1994: NASA Canadians Reunion at NSS/CSS ISDC in Toronto

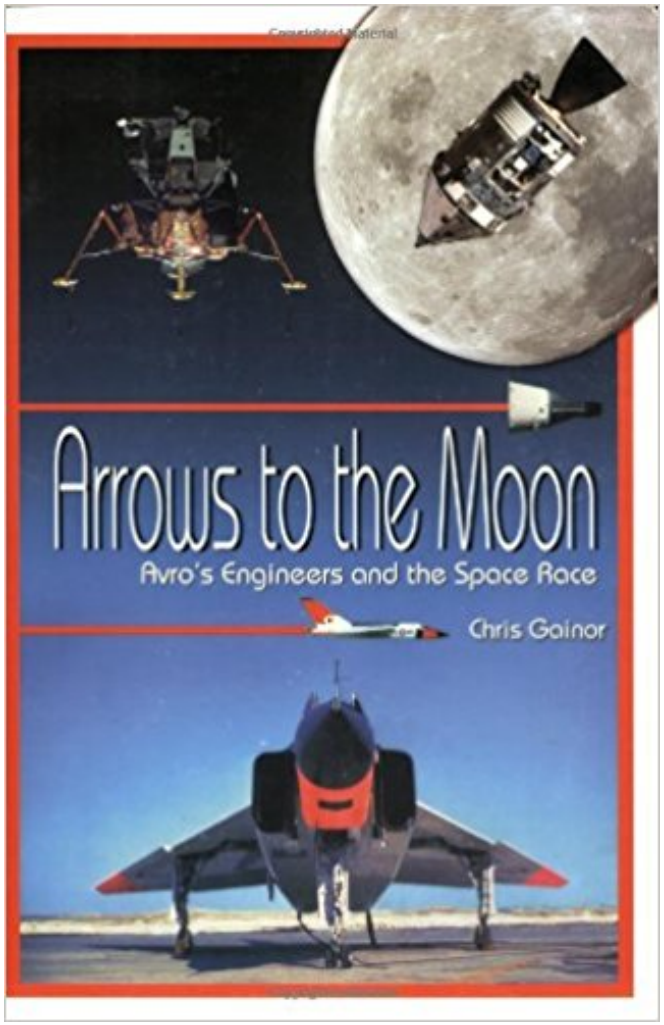
© 1994 Toronto Star

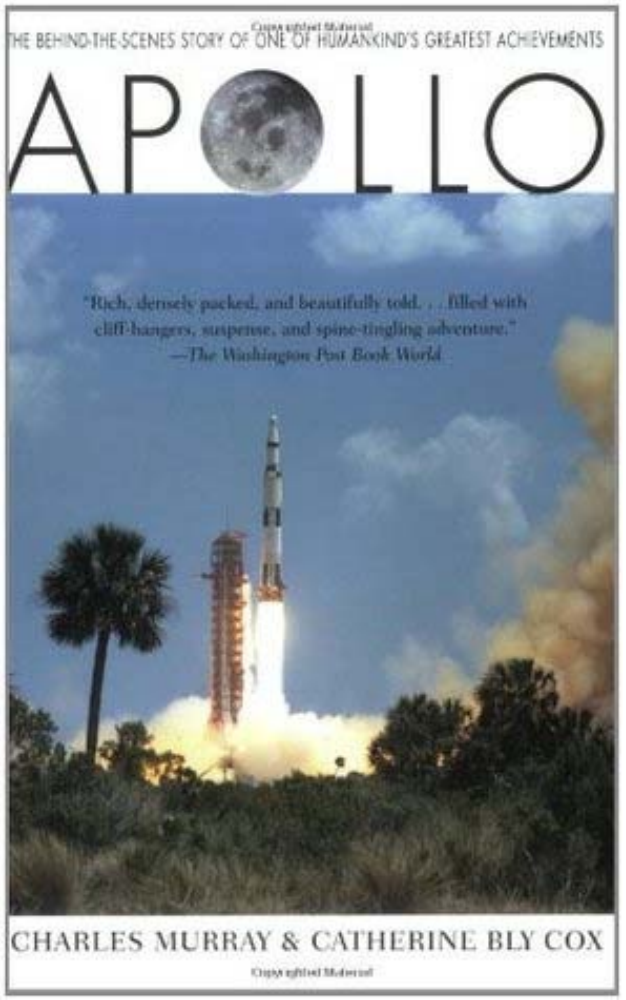
- **ALLM:** 1966 MSC Apollo Lunar Landing Mission Symposium.
- **E&D:** Engineering and Development Directorate (under Max Faget).
- **FCOD:** Flight Crew Operations Directorate (under Deke Slayton).
- **FOD:** Flight Operations Directorate (under Chris Kraft).
- **LRL:** Lunar Receiving Laboratory
- **PMO:** Program Management Office (for Apollo, under Bob Piland, Charlie Frick, Joe Shea, George Low, Jim McDivitt).
- **STG:** Space Task Group
- **MSC:** Manned Space Center (later Johnson Space Center in Houston).
- **MSFC:** Marshall Space Flight Center (Huntsville, Alabama).

- **Bruce A. Aikenhead:** born 22/9/23 in Didsburg, Alberta; E&D, FCOD (training).
- **Peter J. Armitage**: born 5/3/29 in Yorkshire, England; FOD (landing and recovery), Flight Sciences, LRL.
- **David N. Brown:** born 1/9/27 in South Croyden, Surrey, England; E&D.
- **Richard R. Carley:** born 27/4/27 in Saskatoon, Saskatchewan; E\&D (guidance, navigation and control expert).
- **William R. Carpentier:** Medical and Recovery.
- **Frank Chalmers:** FOD (flight control).
- **James A. Chamberlin:** born in Kamloops, British Columbia; PMO (Mercury PM, Gemini PM, Apollo advisor and Boards chairman, Shuttle expert).
- **Jack N. Cohen:** FOD.
- **Thomas V. Chambers:** E&D.
- **Stanley H. Cohn:** FOD.
- **D. Owen Coons:** Medical---Chief (Apollo Boards, Engineering and Operations Interface).
- **Burton G. Cour-Palais:** born 18/4/25 in Najpur, India; E&D, Life Sciences.
- **Eugene L. Duret:** born 25/5/24 in Creelman, Saskatchewan.
- **R. Bryan Erb:** born 12/4/31 in Calgary, Alberta; E&D, Life Sciences, LRL.
- **David D. Ewart:** born 8/2/27 in Stoke-on-Trent, Staffordshire, England; E&D, PMO (at North American).
- **Joseph Farbridge:** E&D (loads expert, and Operations at GSFC).

- **Norman B. Farmer:** born 16/12/27 in London, England; E&D.
- **Dennis E. Fielder:** born 26/8/30 in London, England; FOD.
- **Stanley H. Galezowski:** born 2/12/33 in Toronto, Ontario; E&D.
- **George Harris:** E&D.
- **John D. Hodge:** born 10/2/29 in Leigh-on-Sea, Essex, England; FOD (flight control).
- **John K. Hughes:** FOD.
- **Morris V. Jenkins:** born 3/5/23 in Southampton, England; FOD (mission planning and analysis), ALLM (presenter).
- **Robert Lindley:** facilitated selection of AVRO personnel for STG; later went to MDAC, NASA HQ and GSFC.
- **C. Frederick Matthews:** born 28/11/22 in Guelph, Ontario; FOD.
- **Owen E. Maynard:** born 27/10/24 in Sarnia, Ontario; E&D (Project Engineering, S/C Design Integration), PMO--ASPO (engineering and project management, systems engineering, Mission operations, Operations Management), ALLM (manager and presenter).
- **John Meson:** FOD \& FCOD.
- **Leonard E. Packham:** born 24/1/22 in Saskatoon, Saskatchewan; FOD, E&D.
- **Tecwyn Roberts:** born 10/10/25 in Liverpool, England; FOD & Goddard Networks.
- **Rodney G. Rose:** born 10/8/27 in Huntington Hunts, England; E\&D (through Little Joe for Mercury), PMO (Gemini).
- **John. N. Shoosmith:** born 9/10/34 in London, England; FOD (trajectory software).
- **Leslie G. St. Leger:** born 6/2/22 in Calcutta, India; E&D.
- **Robert E. Vale:** born 8/12/22 in Toronto, Ontario; E&D, Science Payload, Structures and Mechanics Chief, ALLM (presenter).
- **George A. Watts:** born 3/9/28 in Trail, British Columbia; E\&D (loads and structures).

For More Information

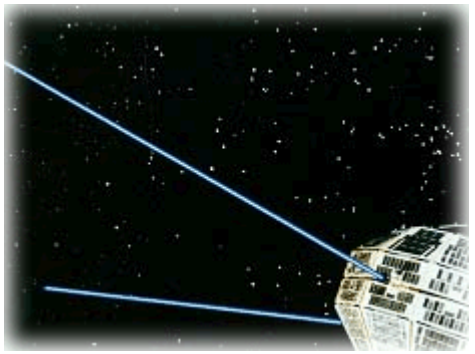




3. 1960s: DHC, SPAR, STEM Tubes

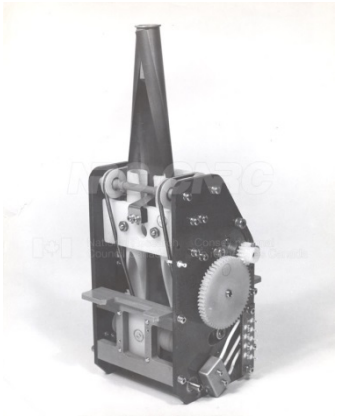
- 1955: George Klein invented the Storable Tubular Extendible member (STEM) at the National Research Council in Ottawa
- Developed by DeHavilland Canada's Special Products division as an antenna for the Alouette satellite
- DHC (later spun off as SPAR Aerospace) developed this as a product, sold into many space applications
- **Used on Gemini and Apollo spacecraft**
- Pathfinder for later Canadarms

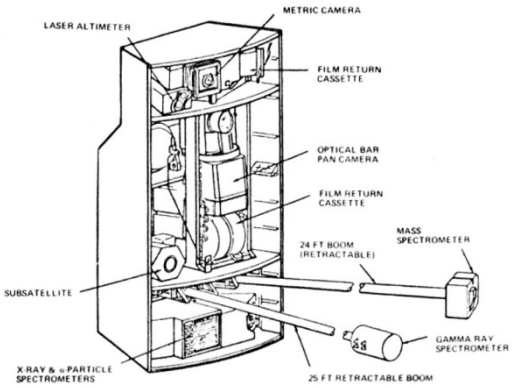
George Klein with prototype STEM system

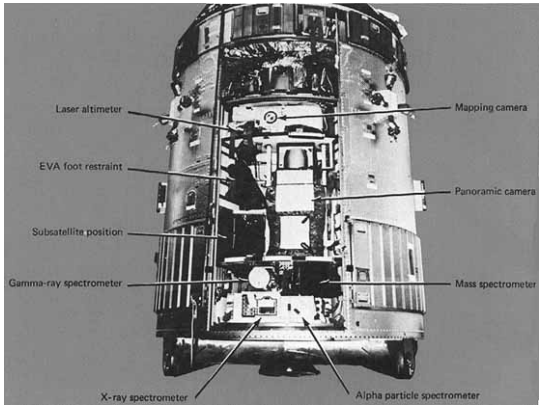


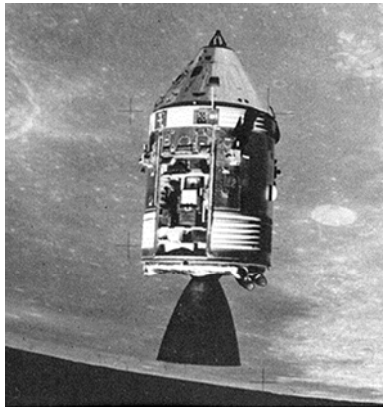
STEM Tubes for Apollo

- E.g., used to deploy and retract gamma-ray spectrometer and mass spectrometer instrument from Service Module Instrument Bay on Apollo 15, 16
- Other applications on Mercury, Gemini, Apollo?
  - Details now difficult to find
  - No longer local…
  - SPAR's STEM division moved to California in the 1980s as part of Astro Research purchase
  - Subsequently Astro was sold to Northrop Grumman









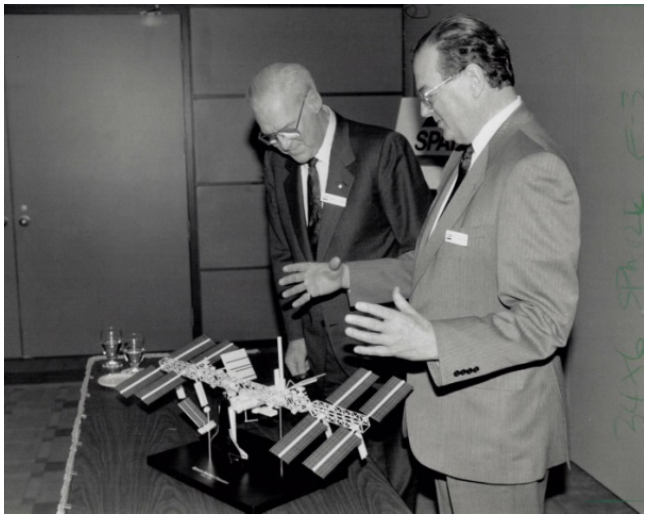
Maynard-STEM-NASA Connection

- Owen Maynard was an RCAF Mosquito pilot in WWII
- Stayed in the RCAF Reserves post-war, in Downsview squadron
- Related to me a story of having seen an engineer from DHC demo a deployable tube to the pilots at the RCAF squadron, “sometime in the 1950s”
  - Aiming to impress the pilots!
  - Hand-held box, hand-cranked
  - Tube kept coming out, extended all the way across the hangar doorway
- When he joined Project Mercury in 1959, Owen mentioned this to Caldwell Johnson (the lead Mercury designer) as a potentially useful device
- Years later, on learning about SPAR, Owen reckoned he provided DHC’s intro to NASA’s manned spacecraft program

George Klein with prototype STEM system

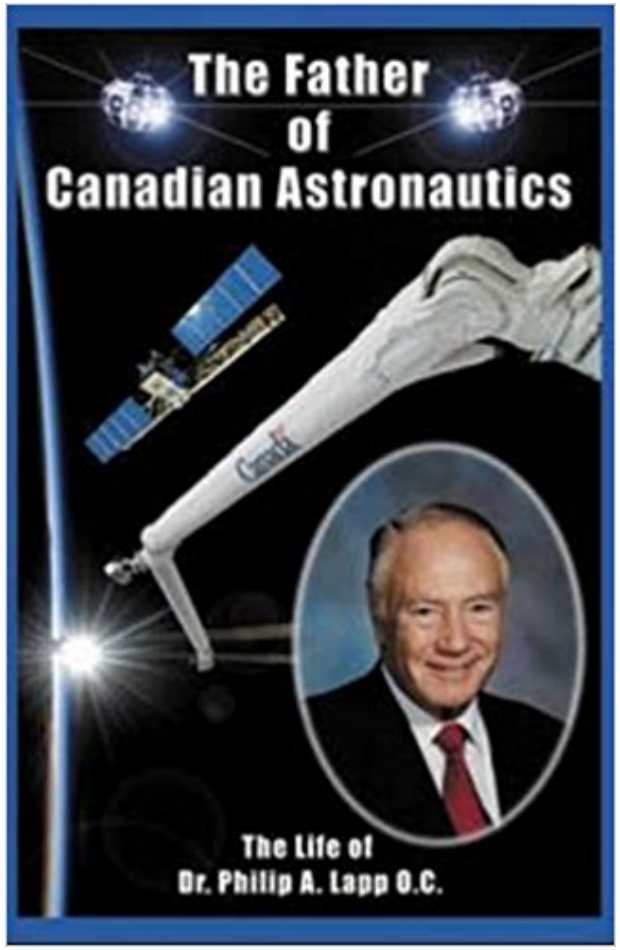
Ca. 1960: DHC People

- **Dr. Philip A. Lapp**
  - Engineering manager for DHC's SP Division
- **John McNaughton**
  - Lead engineer for STEM Tube development and marketing
- Subsequently:
  - 1967: Phil Lapp and Larry Clarke led the spinning-off of the division to become SPAR Aerospace
  - Clarke was CEO and Lapp was on SPAR's Board for many years
  - 1990s: McNaughton became CEO



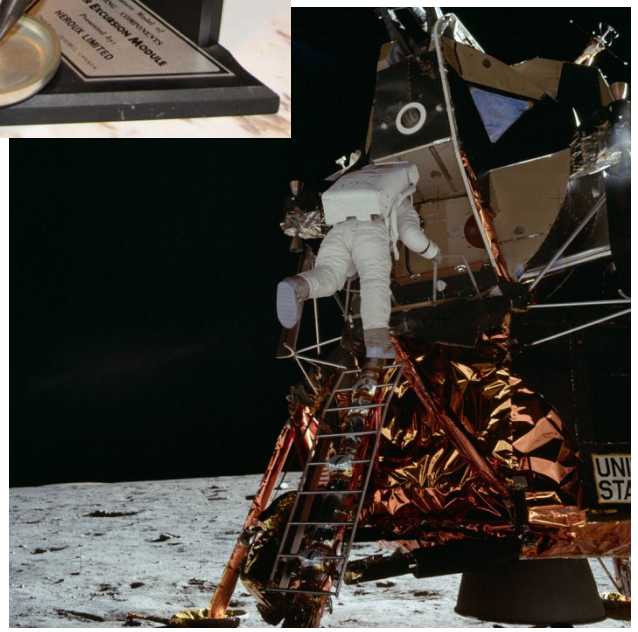
For More Information

- Phil Lapp's autobiography
- Published by Apogee Books



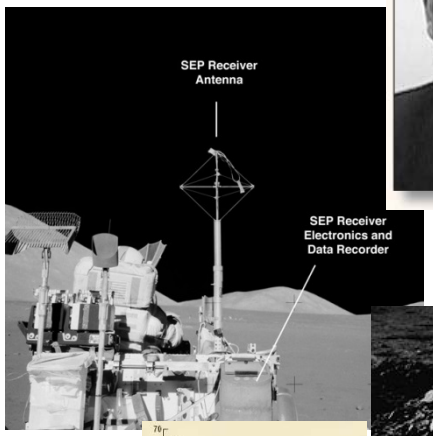
1960s/70s: Apollo Lunar Module Legs

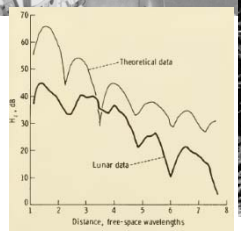
- **Heroux Limited**
  - Located in Longueuil, Quebec
  - Aviation equipment supplier
  - Specialty in landing gear
- Developed legs for the Apollo Lunar Module landing gear
  - Under contract from LM Prime Contractor, Grumman
- Now Heroux-Devtek



Ca. 1970: Apollo Canadian Lunar Scientists

- **Dr. David Strangway**
  - 1952-60: University of Toronto student (physics and geology)
  - 1970: Chief of its Geophysics and Physics Branch at the Johnson Manned Spacecraft Center
    - Designed **Lunar Surface Electrical Properties (SEP) experiment**, carried out by astronauts on the surface of the moon (Apollo 17)
    - Was involved in the examination of returned moon rocks that contributed to the further knowledge of the solar system.
  - 1973-80: U of T Geology Department Chair
  - 1983-84: U of T President
  - 1985-97: UBC President
- **Dr. Peter Annan**
  - University of Toronto and Memorial University, engineering/geophysics
  - His early analytic work was the basis for the SEP experiment
  - Went on to work at NRCan/GSC, became a leading developer of Ground Penetrating Radar instruments





1970s: Viking Upper-Atmosphere Mass Spectrometer

- UAMS attached to Viking entry vehicle aeroshell
  - During entry, made first measurements of Mars atmosphere composition
- Principal Investigator: Dr. Alfred O.C. Nier
  - University of Minnesota physicist
  - Mass spectrometry pioneer
- **Dr. J. Barry French**
  - 1955: B.A.Sc., U of T Chemical Engineering
  - 1962: Ph.D., UTIAS
  - Then joined staff of UTIAS as a prof
  - Hypervelocity aerodynamics, rarified gas dynamics
  - Researching satellite drag reduction
- NASA/Nier approached Barry ~ 1969
  - Barry had a unique Mach-15 h**ypersonic beam upper-atmosphere simulator** --- funded by NASA and the US Naval Ordnance Lab
  - Half the speed of Mars entry
  - Nier otherwise didn't know how to calibrate UAMS, as it was an open source, not an equilibrium one
  - UTIAS facility saved Nier 2-3 years in facility development time

Viking UAMS Design, UTIAS Simulator, Results

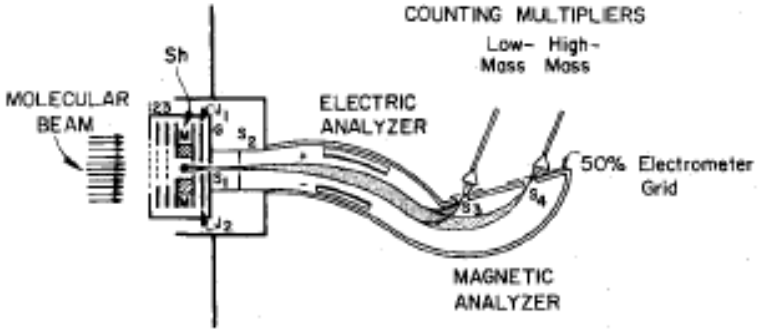
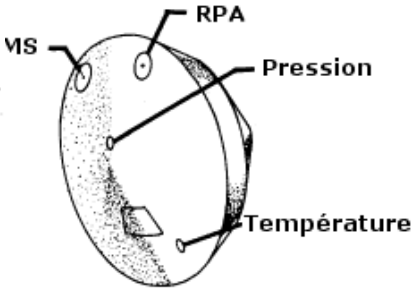
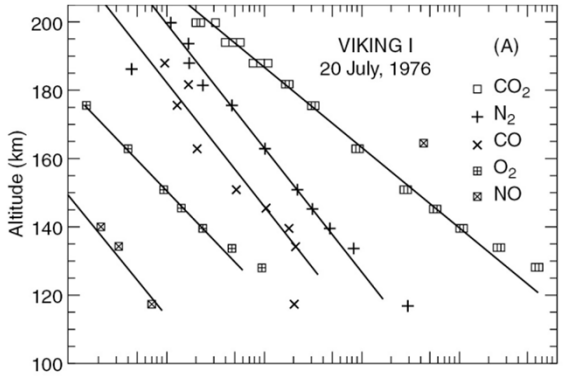


Fig. 1 Ion source and mass spectrometer schematic.





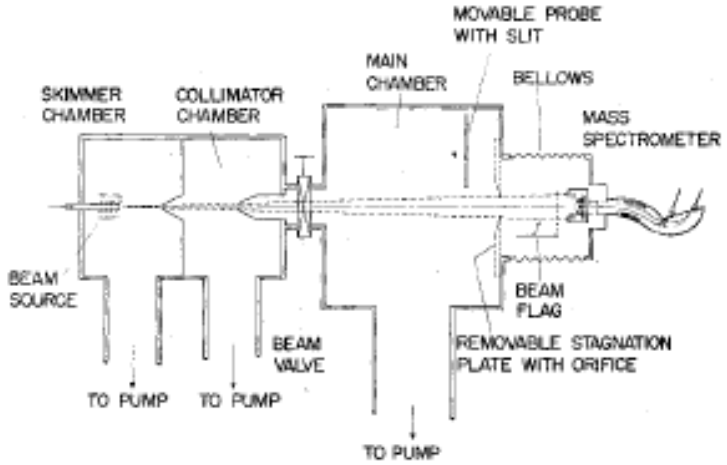
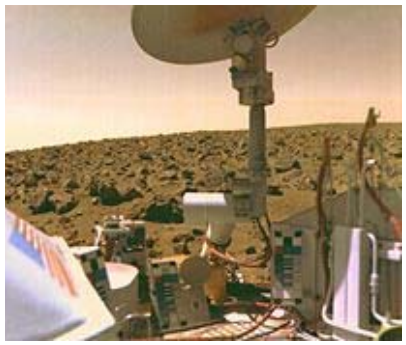
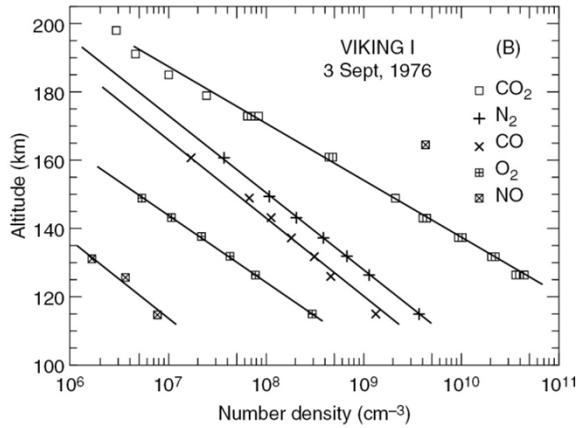


Fig. 2 Molecular beam simulation system.



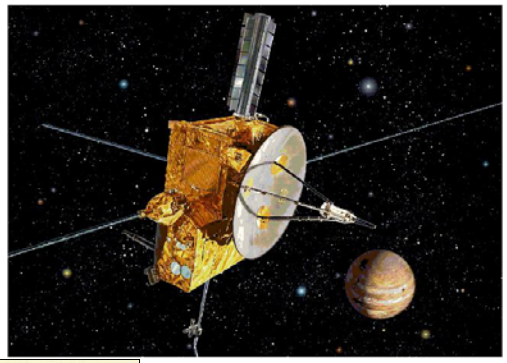


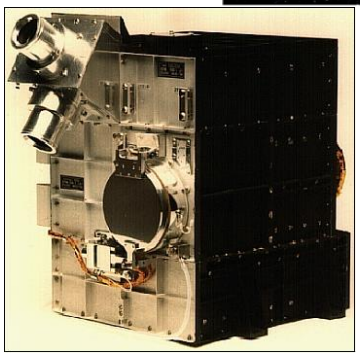
UAMS Led to Sciex

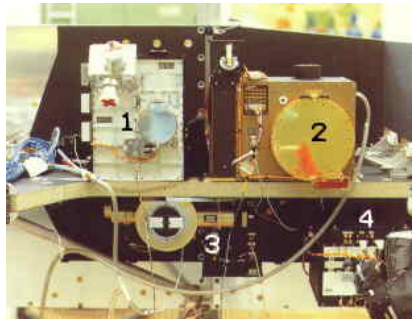
- As a result of UAMS, Barry redirected his UTIAS research towards mass spectrometry
- Developed invetions related to Inductively Coupled Plasma Mass Spectrometry (ICP-MS), trace-gas mass spectrometry
- Mid-70s: Co-founded SCIEX
  - Toronto-area company
  - Developed numerous models of mass spectrometers
  - Now a division of Danaher Corporation
  - World's largest mass-spectrometer producer
- Mid-1990s: Co-founded Gedex
  - Toronto-area company
  - Terrestrial and space gravity geophysics exploration

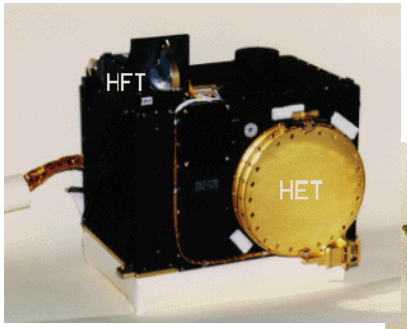
1980s: Ulysses High Flux Telescope (NRC HIA)

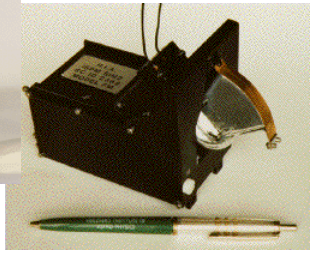
- Ulysses Solar-Polar mission
  - **Included a Jupiter flyby**
- Part of the COsmic ray and Solar Particle INvestigation (COSPIN)
  - Suite of five sensors
  - Measure energetic nucleons and electrons over a wide range of energies.
- COSPIN Principal Investigator:
  - Dr. R. Bruce McKibben, Uuniversity of New Hampshire
- **High Flux Telescope (HFT)**
  - ~0.3-7 MeV protons, 0.4-4 MeV/n He with a small aperture single detector telescope for use in very high flux situations
- HFT Co-Investigator:
  - **Dr. John David Anglin**, Herzberg Institute for Astrophysics, National Research Council of Canada







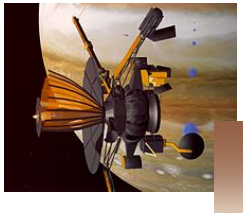
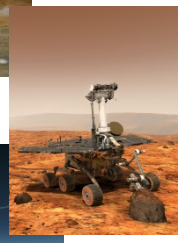




1980s: JPL Planetary Missions

- **Paul and Janis Chodas**
  - UTIAS Spacecraft Dynamics and Controls group
  - Janis: M.A.Sc., 1980; Paul: Ph.D., ~1986
- Both joined JPL in the 1980s, both have worked on several planetary exploration missions
- Janis:
  - Galileo (Jupiter)
  - Cassini (Saturn)
  - Mars Exploration Rovers
  - Project Manager for JUNO (Jupiter)
- Paul:
  - Magellan (Venus radar mapping orbiter)
  - Asteroid Redirect Mission (asteroid sample-return)
  - Now Manager of the NASA NEO Program Office (asteroids)



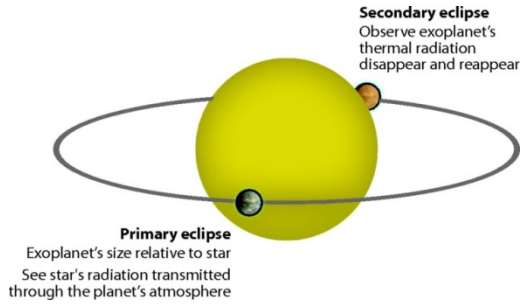




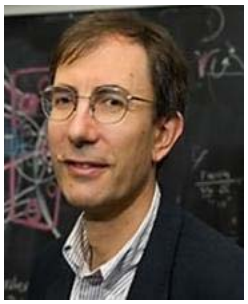

1995-2003: Thermal Plasma Analyzer

- Japanese Nozomi spacecraft
  - Mars orbiter (was “Planet-B”)
  - ISAS, University of Tokyo
  - Upper atmosphere science
  - Launched 1998
  - (Failed to enter Mars orbit, due to a propellant valve malfunction)
- **Thermal Plasma Analyzer** instrument
  - *First planetary instrument funded by CSA*
  - To measure thermal-energy ions in the topside ionosphere of Mars and suprathermal ions and electrons in the Martian magnetosphere and magnetotail
- **Prof. Andrew Yau**
  - TPA Principal Investigator

2003: MOST

- "Microvariability and Oscillations of Stars"
- First Canadian microsatellite mission
- Canada's "Humble Space Telescope"
- Objectives:
  - Stellar photometry
  - Asteroseismology
  - **Searching for Exoplanet transits**
- Principal Investigator: Jaymie Matthews, UBC
- Exoplanet Co-I:
  - **Dimitar Sasselov**, Harvard-Smithsonian Center for Astrophysics
  - 1990: Ph.D. in Astronomy, University of Toronto
  - Supervised Ph.D. student **Sara Seager** on this topic
  - Sara's B.Sc. Is from University of Toronto
  - Now a Professor at MIT, researching Exoplanets





2011: MOST Detection of Exoplanet 55 Cancri e

[Winn, Matthews, Sasselov et al., "A Super-Earth Transiting a Naked-Eye Star," Astrophysical J. Lett., 22 July 2011]

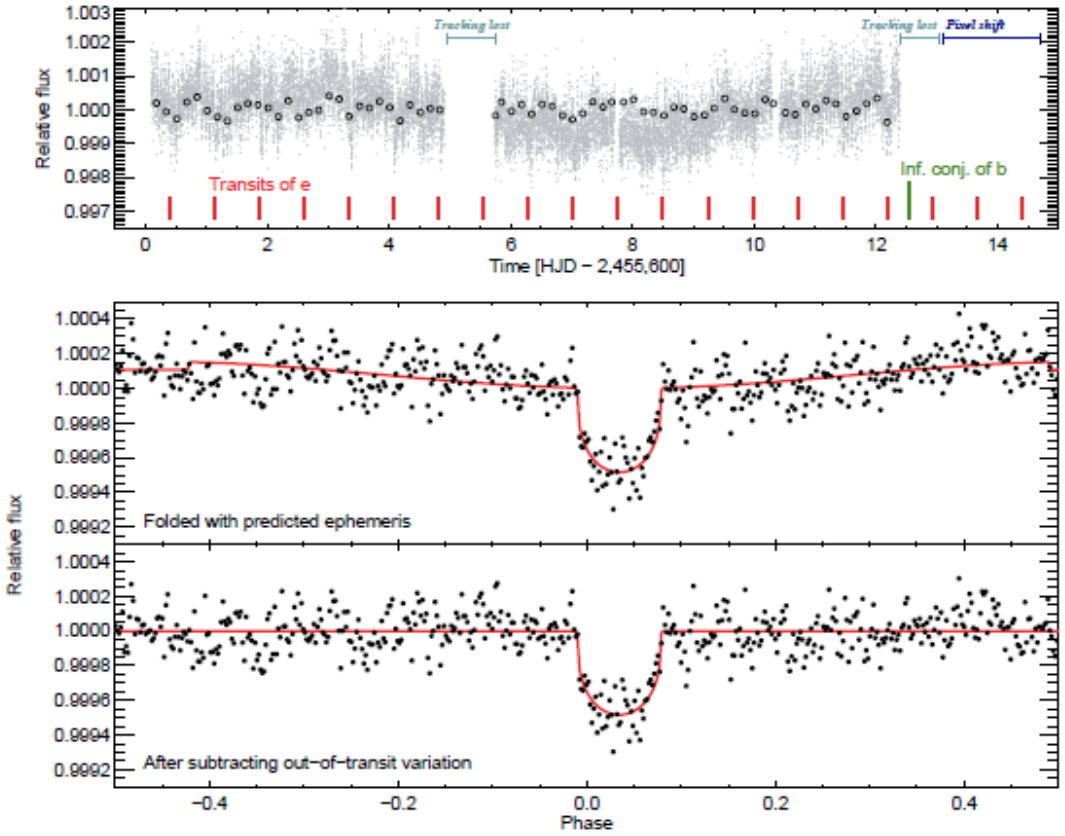


FIG. 1.— *MOST* **photometry of 55 Cnc.** *Upper.*—The time series, after decorrelation (small gray dots) and after further correction with the running averaged background method (large open circles, 0.25 d averages). Vertical bars mark the predicted transit times of planet e, and the inferior conjunction of planet b (which was missed during a failure of fine tracking). *Middle.*—Phased light curve, folded with $P = 0.736540$ d and T_c [HJD] = 2,453,094.6924 (Dawson & Fabrycky 2010) and averaged into 2 min phase bins. The solid curve is the best-fitting model. *Bottom.*—Same, but with the best-fitting model of the out-of-transit variation has been subtracted from the data.

A SUPER-EARTH TRANSITING A NAKED-EYE STAR*

JOSHUA N. WINN[1], JAYMIE M. MATTHEWS[2], REBEKAH I. DAWSON[3], DANIEL FABRYCKY[4,5], MATTHEW J. HOLMAN[3], THOMAS KALLINGER[2,6], RAINER KUSCHNIG[6], DIMITAR SASSELOV[3], DIANA DRAGOMIR[5], DAVID B. GUENTHER[7], ANTHONY F. J. MOFFAT[8], JASON F. ROWE[9], SLAVEK RUCINSKI[10], WERNER W. WEISS[6]

ApJ Letters, in press

ABSTRACT

We have detected transits of the innermost planet "e" orbiting 55 Cnc ($V = 6.0$), based on two weeks of nearly continuous photometric monitoring with the *MOST* space telescope. The transits occur with the period (0.74 d) and phase that had been predicted by Dawson & Fabrycky, and with the expected duration and depth for the crossing of a Sun-like star by a hot super-Earth. Assuming the star's mass and radius to be $0.963^{+0.051}_{-0.029}\ M_\odot$ and $0.943 \pm 0.010\ R_\odot$, the planet's mass, radius, and mean density are $8.63 \pm 0.35\ M_\oplus$, $2.00 \pm 0.14\ R_\oplus$, and $5.9^{+1.5}_{-1.1}$ g cm^{-3}. The mean density is comparable to that of Earth, despite the greater mass and consequently greater compression of the interior of 55 Cnc e. This suggests a rock-iron composition supplemented by a significant mass of water, gas, or other light elements. Outside of transits, we detected a sinusoidal signal resembling the expected signal due to the changing illuminated phase of the planet, but with a full range (168 ± 70 ppm) too large to be reflected light or thermal emission. This signal has no straightforward interpretation and should be checked with further observations. The host star of 55 Cnc e is brighter than that of any other known transiting planet, which will facilitate future investigations.

Subject headings: planetary systems — planets and satellites: formation, interiors — stars: individual (55 Cnc)