

Pratt & Whitney Space Propulsion



Charles A. Chase

42+ Years as a “Rocket Scientist”

10 September 1962 to 28 January 2005



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P&W Space Propulsion

The Start of a Career

- Charles was interviewed at the University of Michigan during the summer of 1962 while completing his Masters Degree in Aeronautical & Astronautical Engineering
- He and his wife Carole (also a U of M Masters [Math Education] graduate) moved to California in early September, 1962
- On September 10, Charles started work at what was then called: United Technology Corporation (UTC), a subsidiary of United Aircraft (UA). The name soon changed to United Technology Center, Division of UA.
- UTC's primary offices were then located on Arques Avenue in Sunnyvale, CA about a block off of what was then called Lawrence Station (not "Expressway"), a two lane road. Near the office were cows and fertile fields growing various crops.



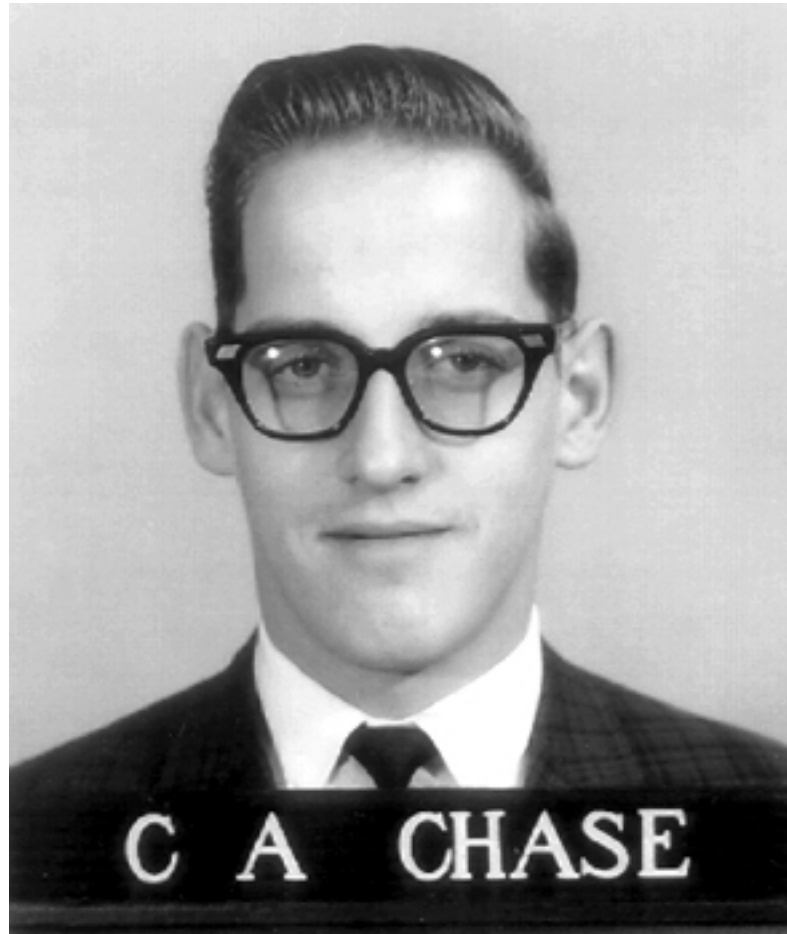
MichiganEngineering



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Early Badge Picture

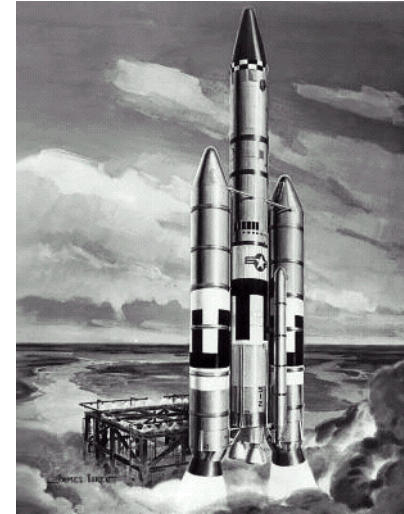


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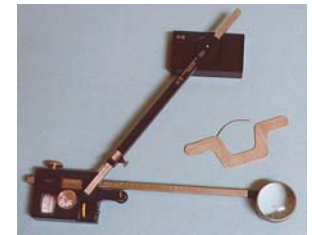
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His First Job Assignment

- Early in 1962, UTC had won an Air Force contract to build the strap-on boosters for the new Titan IIIC. These boosters were the world's largest solid rocket motors at that time
- Charles first worked in the Grain Design and Performance Analysis section. He primarily worked on the ballistics analysis of the Titan SRM forward closure grain which was perforated by a star core and two Thrust Termination (TT) ports.
- All calculations were done using “map readers,” “planimeters,” Friden calculators, slide rules and a very primitive IBM computer. It took 45 minutes for the IBM to make calculations for a single time in the motor burn time.



on Calculator



Planimeter



Keuffel & Esser (K & E) Slide Rule

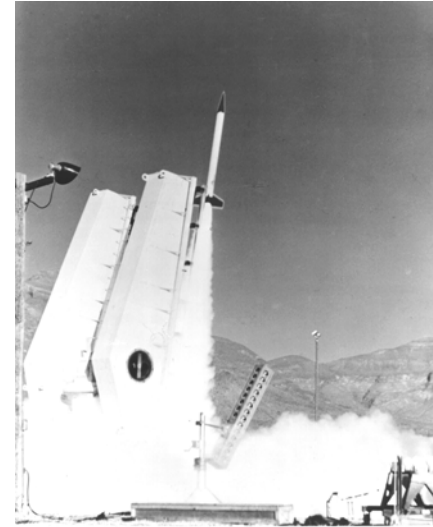


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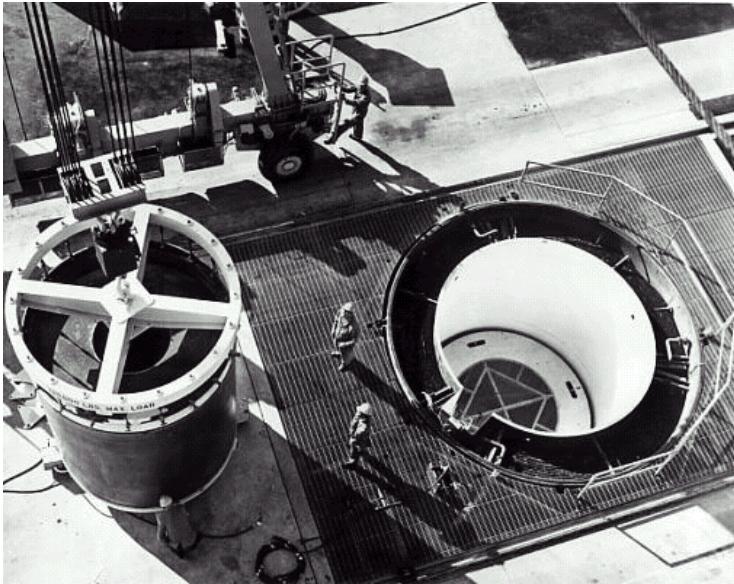
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His First Job Assignment + More College

- Assignments gradually expanded to include some preliminary trajectory parameter assessments
 - This included the development of an improved multi-dimensional trajectory analysis program
- From 1963 to 1968 Charles also attended Stanford University (while working full time) where he earned a Degree of Advanced Engineering-DAE (post-Masters degree) in Aero & Astro Engineering — Thesis: “Performance of Dual Area Nozzles”



CSD Creates Titan Booster “Building Blocks”



Titan Booster Segment
Removed from CSD's
Propellant Casting Pit



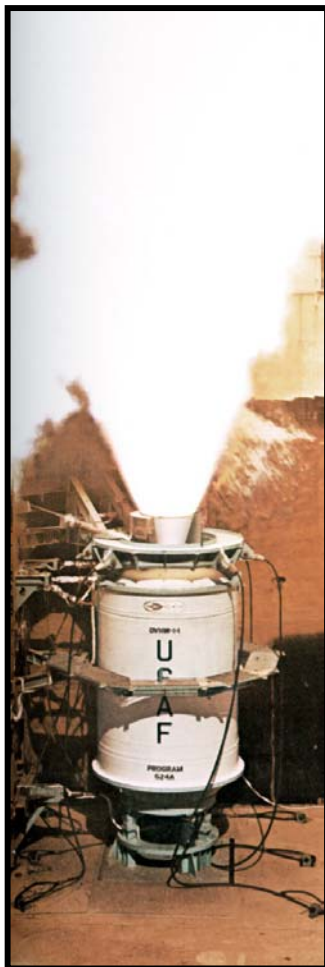
Segment “Stacking” at
CSD's ST-9 Static Test Facility

P0001353



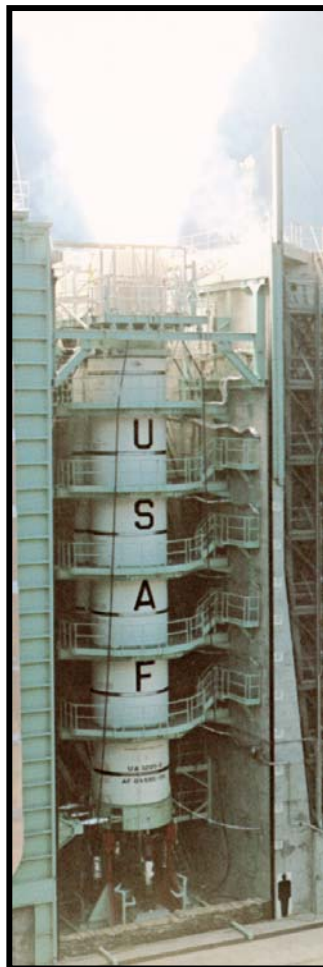
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Key Titan SRM Static Tests



P0001354

First 1201 Test (2/63)



P0001355

First 1205 Test (7/63)



P0001356

First 1207 Test (4/69)



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The Drama of a Titan Static Test at CSD



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CSD Boosters are Integrated into Titan LV



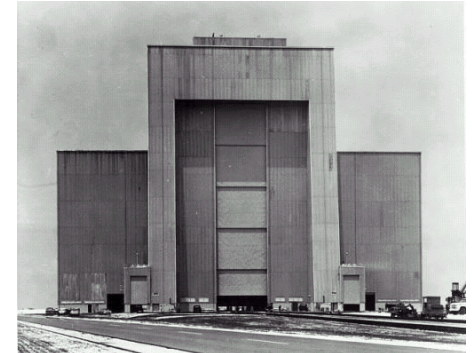
Segments Arrive
at Cape by Rail



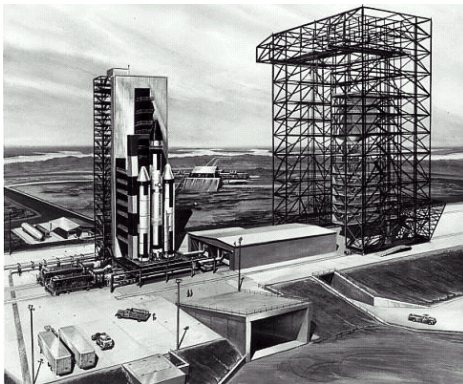
Aerial View
Cape Canaveral



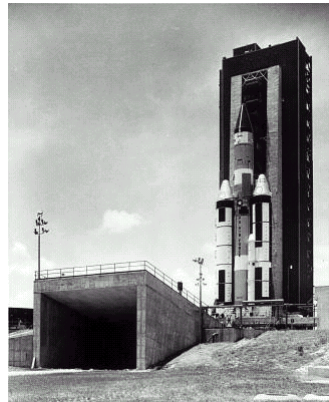
Rail Car for
SRM Buildup



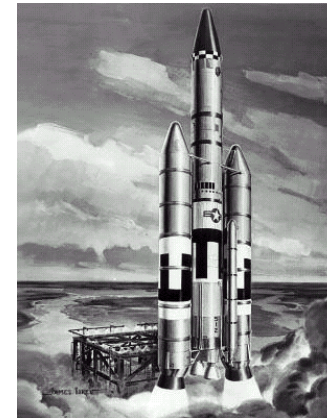
Solid Motor
Assembly Bldg (SMAB)



Titan LV Arrives
at Pad by Rail



Titan IIIC
Ready for Launch



Sketch of
Liftoff at Cape



Sketch of
Booster Separation



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TITAN LAUNCHES-Using CSD Boosters



Titan III

**1st Launch
1965**



Titan 34D

**1st Launch
1982**



Titan IVA

**1st Launch
1989**

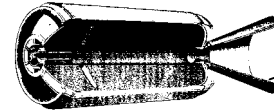


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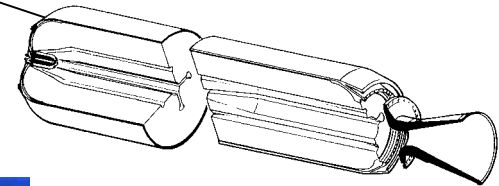
Design/Project Engineer (1962-1971)

- Some of the early programs for which Charles made significant contributions (grain design and performance analysis) include:
 - 5-segment Titan boosters (420,000 lb of propellant) first flown in June 1965 (all 34 flights had 100% success)
 - FW-4, a 19-in diameter filament wound (fiberglass) spin stage (up to 200 rpm) which was the 4th stage for NASA's Scout Launch Vehicle. 67 FW-4s were flown with only one failure (the problem was identified to NASA before the launch)
 - Algol-III: booster stage for NASA's Scout Launch Vehicle — 100% success on all 35 launches
 - FW-5: apogee kick stage for Hughes' Anik satellite (100% success), also used for Westar, Palapa, etc. for a total of 17/17 successful missions

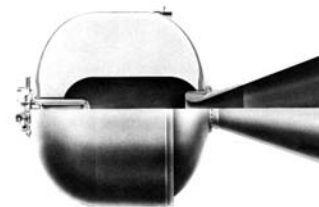


Scout 4th Stage
FW-4 19.6-in diameter
Wp = 605-lb

Scout Booster Stage
Algol-III: 45-in. diameter
Wp = 28,000-lb



Scout Launch



FW-5 AKM



Anik-1



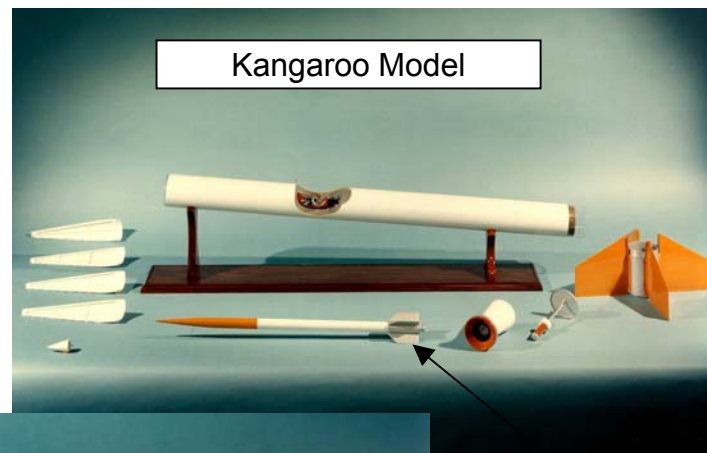
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First Complete Launch Vehicle Built by UTC:

Kangaroo Meteorological Rocket: 1968-1970

- This was a perfect project for a young engineer. Responsibilities included overseeing design, fabrication, dart ejection testing, static tests (4), launches (3) and radar tracking, etc. One of the amazing things is that the above was completed on-budget for \$125K.
- The strange requirement to shot a meteorological dart out of a canister contained within the booster rocket's combustion chamber resulted in many unique design features
- Two launches from San Nicholas Island (Point Mugu) were never properly tracked by the Navy. A final launch at White Sands clearly showed success.

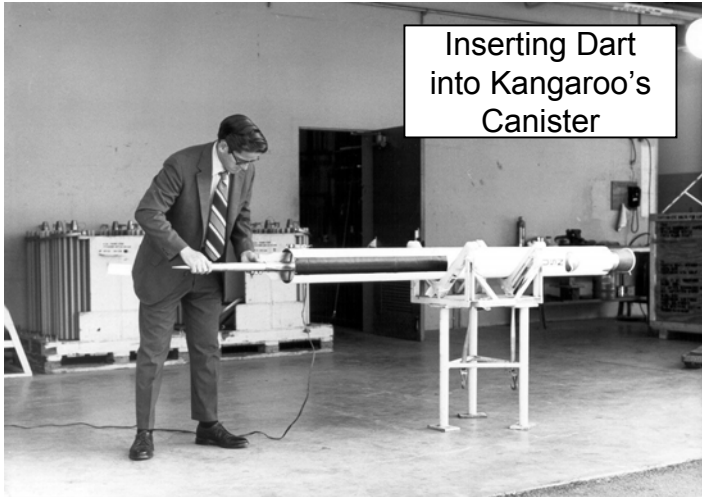


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A Hands On Kind of Guy

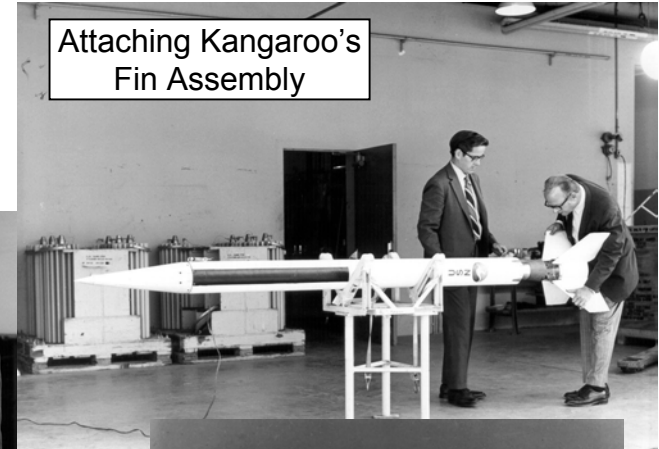
Kangaroo Meteorological Rocket



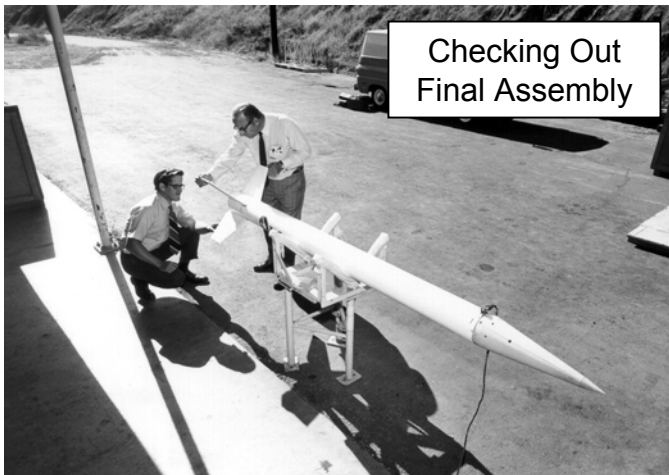
Inserting Dart
into Kangaroo's
Canister



Attaching Kangaroo's
Nosecone (Baked
in Motel Room Oven)

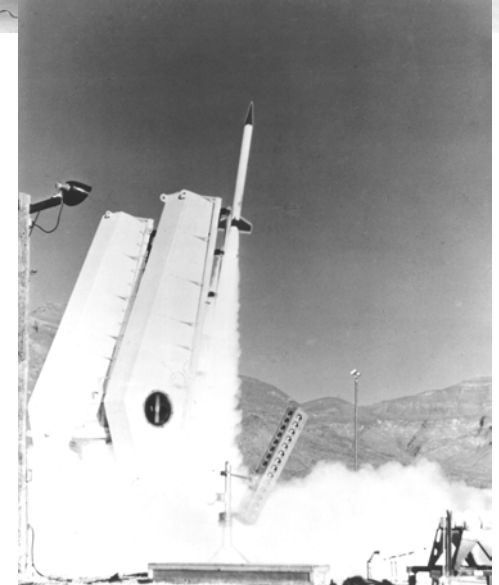


Attaching Kangaroo's
Fin Assembly



Checking Out
Final Assembly

Launch at
White Sands, NM

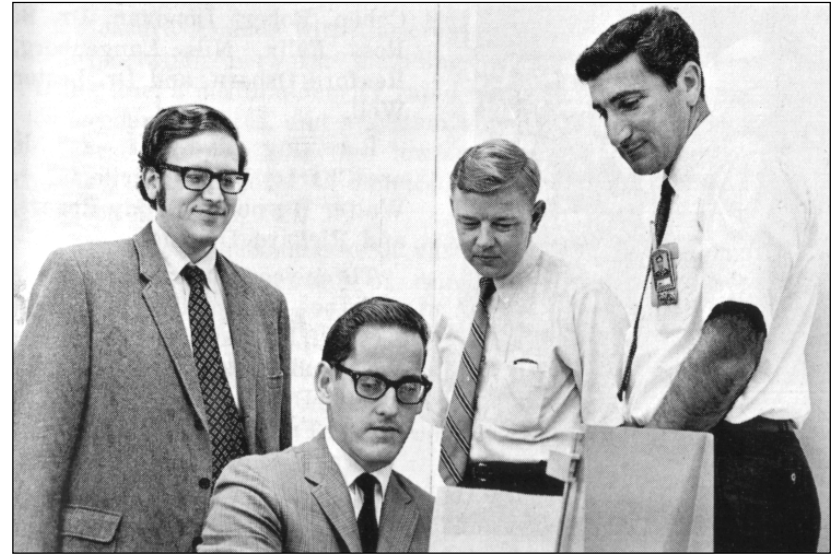


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Chief, Advanced Design (1971-1976)

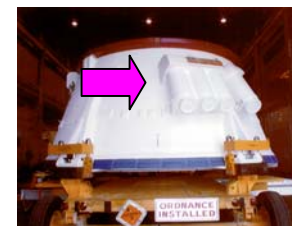
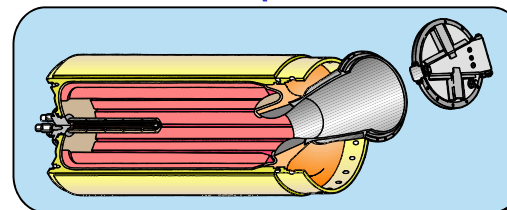
- Directed a staff of about 25 engineers responsible for all solid propulsion optimization studies, grain design activities, and performance (internal ballistics and trajectory) analyses; and all computer models used in motor systems optimization, internal ballistics, and trajectory analyses
 - Also directed technical activities in support of most UTC solid rocket proposal efforts
-
- In 1975, company name changed to Chemical Systems Division, a Division of United Technologies Corporation (not United Aircraft anymore)



Chief Engineer

Space Shuttle Booster Separation Motors (1975 to 1978)

- Directed all BSM technical activities from proposal writing through motor and nozzle cover early qualification
- Significant design challenges included:
 - Only solid rocket in history to perform forward of a manned vehicle
 - Close proximity to Space Shuttle Orbiter severely limited allowable ejecta from motor
 - This required low aluminized propellant and a unique nozzle cover — a bigger challenge to develop than the motor
- 1792 BSM's have flown to date (as of 1/28/05) with 100% success



BSM Team in 70s vs 2004

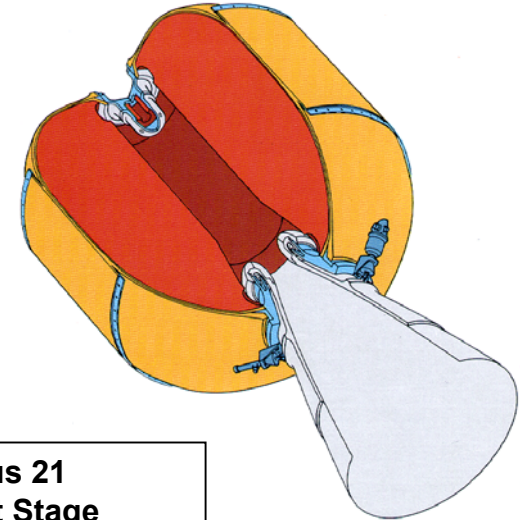


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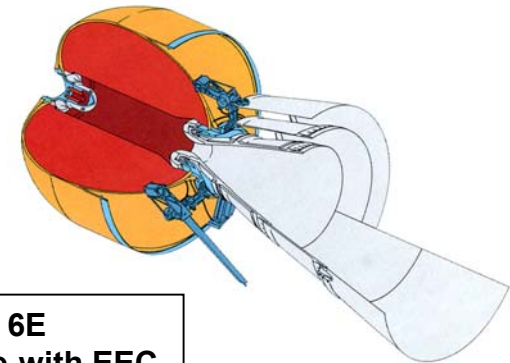
Chief Engineer

Inertial Upper Stage (IUS) Program (1976 to 1984)

- 1973 to 1975: worked with senior management to create idea of solid rocket (instead of liquid rocket) IUS. Convinced Boeing to team with UTC. Changing “I” from “Interim” to “Inertial”
- 1976 to 1977: technical director of IUS 18-month validation phase resulting in a full-scale high technology motor firing 15 months after ATP. This test provided the Air Force with the confidence to proceed into IUS full-scale development.
- 1978 to 1984: directed all systems optimization studies, design and analysis and test activities that led to the full-scale qualification and flights of the two-stage IUS system



**Orbus 21
IUS 1st Stage**



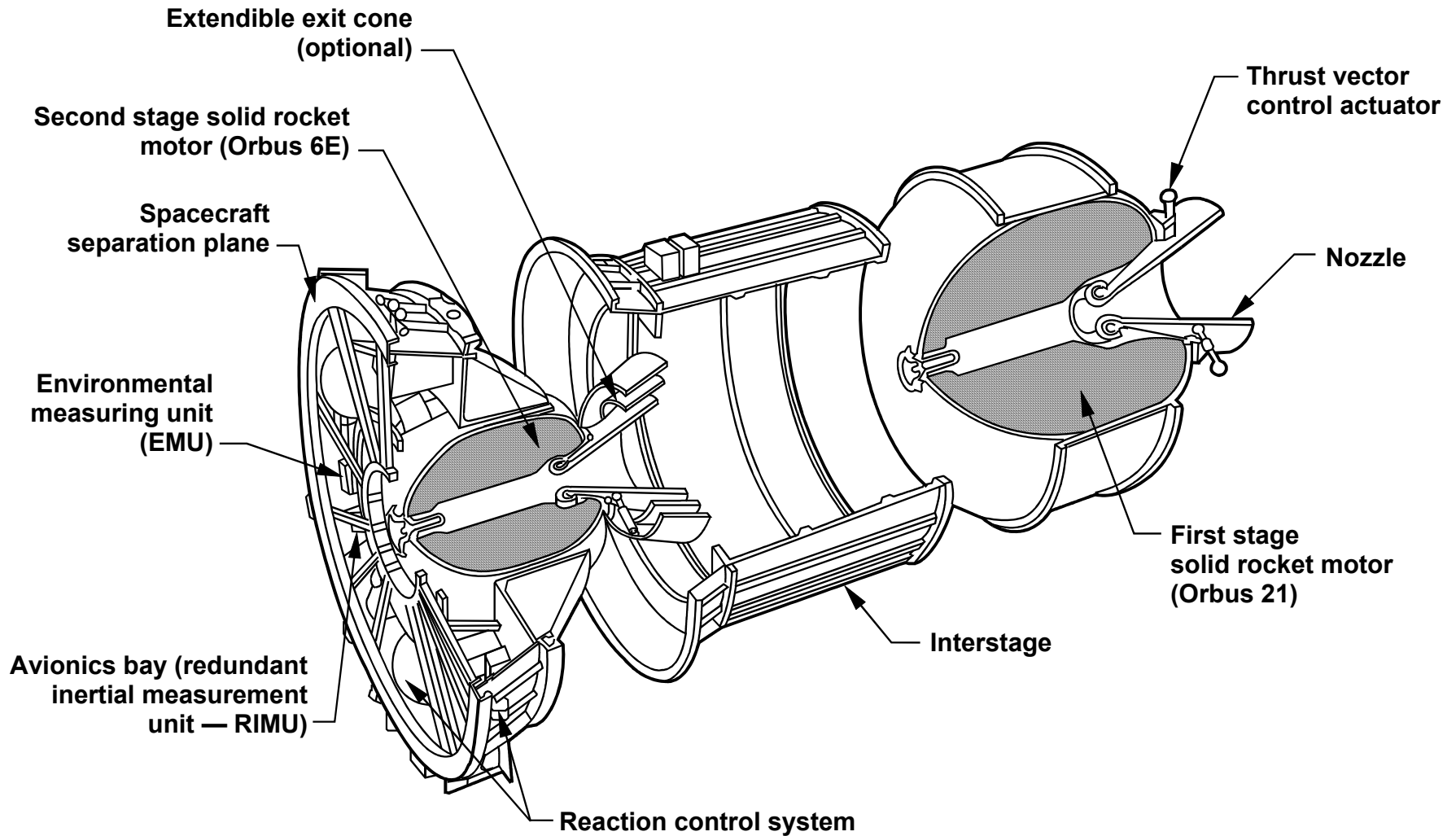
**Orbus 6E
IUS 2nd Stage-with EEC**



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IUS Two-Stage Vehicle



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Inertial Upper Stage (IUS)

Key Propulsion Systems Design Challenges

- Longest burn time of any SRM (155 to 165 sec)
 - Major challenge for nozzle materials to maintain nozzle expansion ratio
- Largest SRM space motor
- Very early use of Kevlar/epoxy for motor case
- Very early use of carbon/carbon for nozzle throat and exit cone
- First nozzle in the world qualified for flight using an extendible exit cone (EEC)
- Both Stage 1 and 2 SRMs had to be capable of propellant offloads up to 50%
- Had to be qualified for flight on both Titan and Shuttle
- Electromechanical thrust vector actuators (TVAs) must incorporate redundant electric drive motors (another first in the world)



Signing IUS Case CDR Poster

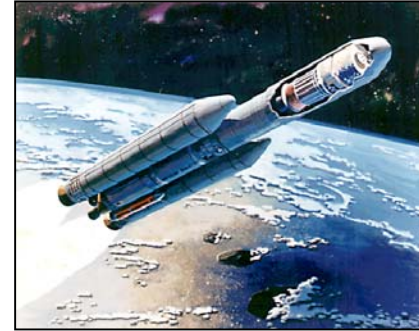


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Chief Engineer

Inertial Upper Stage (IUS) Program (1976 to 1984)

- During FSD, CSD tested a total of 26 first stage (Orbus 21) and 2nd stage (Orbus 6E) IUS motors, all at AEDC in Tennessee
- IUS was qualified for flight on both Titan and the Space Shuttle launch vehicles
- First flight of IUS was on the maiden flight of the Titan 34D at midnight on Halloween — October 30, 1982
- First flight of IUS on the Space Shuttle occurred on April 3, 1983
 - This resulted in a flight “anomaly” which shut IUS flights down for about 18 months while a series of “most probable” causes were eliminated
 - We had 90 “non-CSD personnel” on site to assist in this investigation



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Some Key IUS Missions

- IUS was on Challenger when it exploded during launch in January 1986. It was also in the Shuttle cargo bay when Shuttle returned to flight in late 1987.
- Some of the primary missions have included:
 - DSCS spy satellites
 - TDRS communication satellites for Shuttle Orbiter communications
 - Magellan Spacecraft to Venus
 - Galileo Spacecraft to Jupiter
 - Ulysses Spacecraft to the Sun
 - DSP military spy satellites
 - Chandra X-ray Telescope



TDRS



Magellan



Galileo



Ulysses



DSP



Chandra



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Chase Helps Host Visiting Shuttle Astronauts



Welcome to CSD (Mullane and Coats)



Explaining IUS Propulsion
(Hartsfield, Mullane, Resnick, Coats)



Explaining Shuttle BSM Propulsion
(Hartsfield and Resnick)



Judy Resnick and Dan Nuzzo



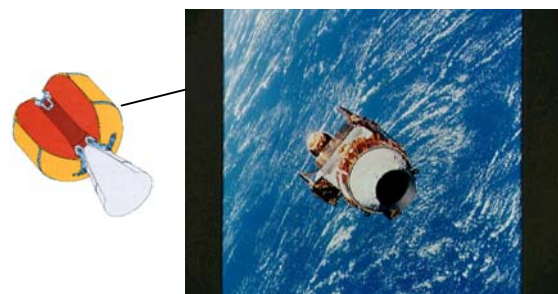
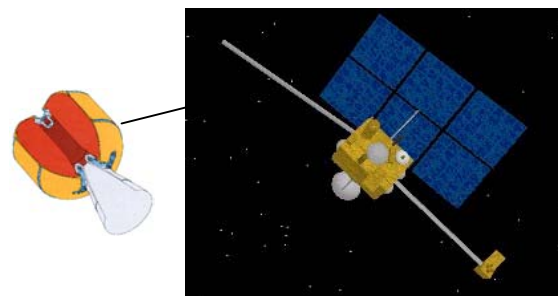
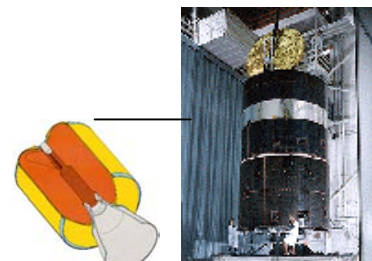
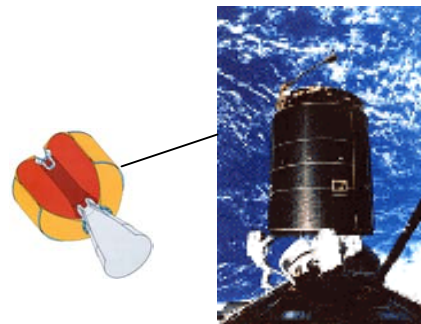
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Other Space Missions

Chief Engineer, Space Propulsion Systems (1984 to 1995)

- Directed the activities of the Chief Engineering staff in charge of all CSD space motor programs.
 - IUS
 - Intelsat VI (Orbus 21S)
 - JCSat (Orbus 7S) for Hughes
 - TOS for Orbital Sciences
 - Mars Observer (Orbus 21) launched successfully on September 25, 1992 by Titan from Cape Canaveral
 - STS-051 09/12/93 ACTS/TOS (Orbus 21) after release from Shuttle Discovery — Advanced Communications Technology Satellite (ACTS)



Miscellaneous Orbus Motor/System Pictures



Orbus 21 in prep at CSD

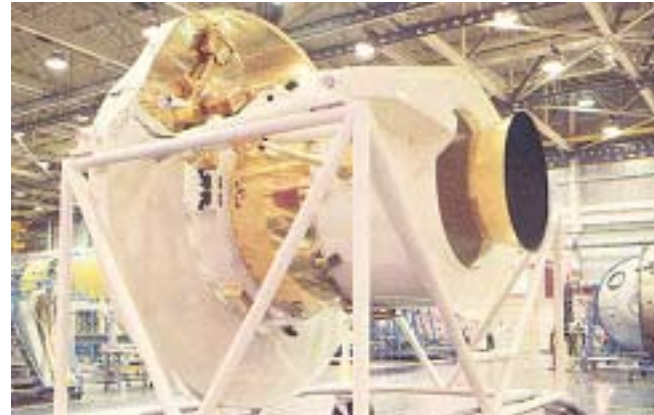


Orbus 6E in prep at CSD



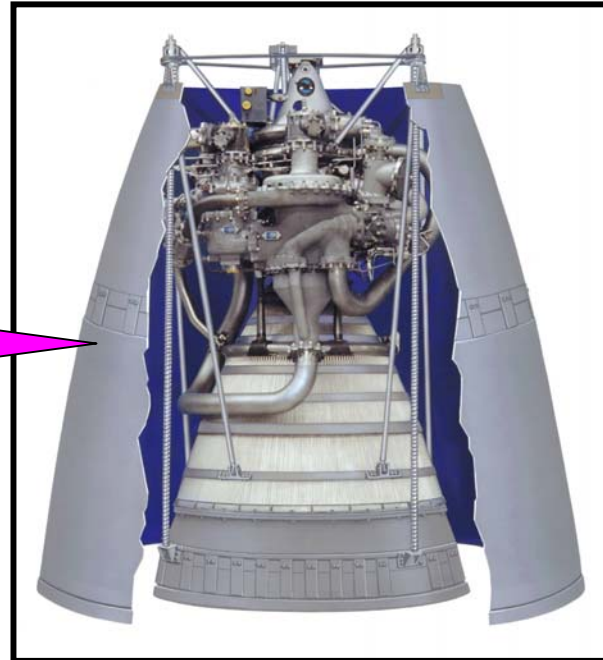
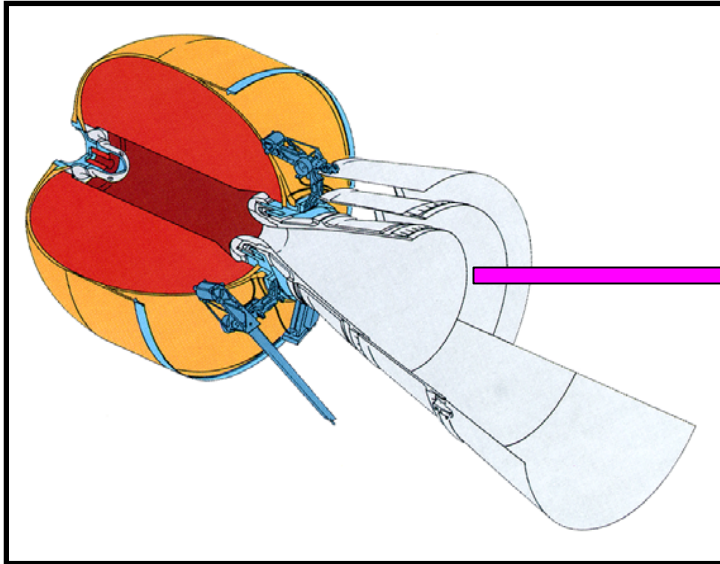
IUS awaiting vacuum chamber at Boeing

TOS checkout
at
Lockheed Martin



Orbus 21
On TOS

Example of Solid Rocket Motor Technology *Being Applied to a Liquid Rocket Engine*



Carbon/carbon extendible nozzle technology of IUS's Orbus 6E SRM transferred to RL 10B-2 LRE of Delta III/IV's Upper Stage



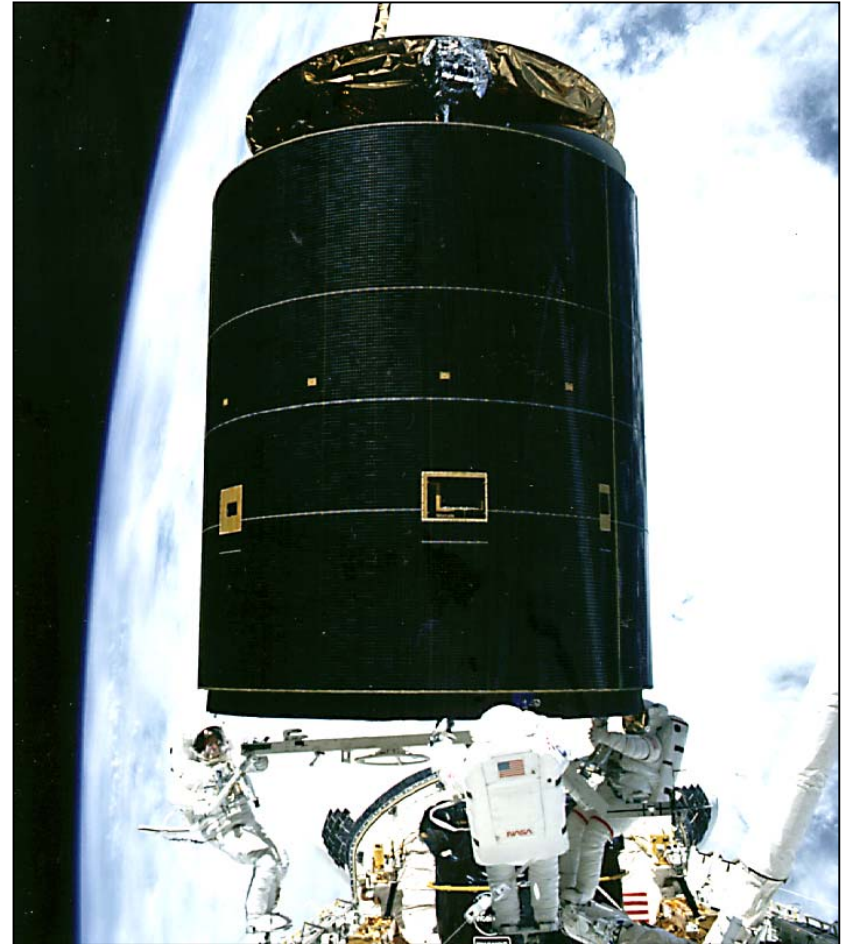
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Rescue of Wayward Intelsat VI Satellite-1992

Astronauts Connect it to Orbus 21S

- In 1990, an Intelsat VI was launched on a Commercial Titan. Unable to separate CSD's Orbus 21S from the upper stage of the Titan, the Intelsat VI was parked in a useless orbit (about 300 nm)
- In 1992, a Shuttle mission was assigned to rescue the Intelsat VI. After several days, the astronauts attached the Intelsat to a new Orbus 21S. After separation from the Orbiter, the Orbus 21S placed the Intelsat VI into the desired transfer orbit.



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Chase the Marathoner--1984



Runners of San Francisco Marathon:
Dan McMahon, Chuck Chase and Bob McLaughlin



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Chase Directs Studies for New Launch Vehicle

Lockheed Launch Vehicle(LLV) →→ Athena I and II

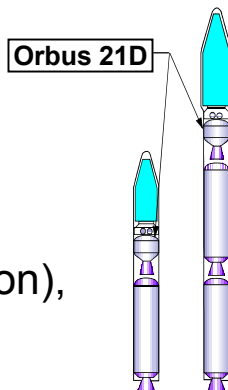
- Early studies evaluated potential use of an Orbus 21-class motor for use as an upper stage atop a Castor 120
- The nozzle exit cone material was changed from carbon-carbon to carbon phenolic to withstand “hot” stage separation loads. The resultant motor was called the Orbus 21D.
- Key payloads have included “Lunar Prospector” (discovered ice on the moon), “ROCSAT” (Taiwan’s 1st satellite) and Ikonos (with 1-meter photo resolution)



**Orbus 21D
Static Test**



**Orbus 21D being
stacked on launch pad**



**Athena I and II Launches
with Orbus 21D Upper Stage**



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Chase Chairs National Red Team for THAAD

Challenge: Eliminate Combustion Instability

- Early THAAD booster motor had design characteristics that promoted combustion instability that could not be tolerated
- Chase chaired a red team composed of the nation's most noted experts in the field of combustion stability analysis
- Eventually, through an excellent computational fluid dynamics (CFD) analysis, the THAAD propellant grain was re-configured
- The instability problem was eliminated

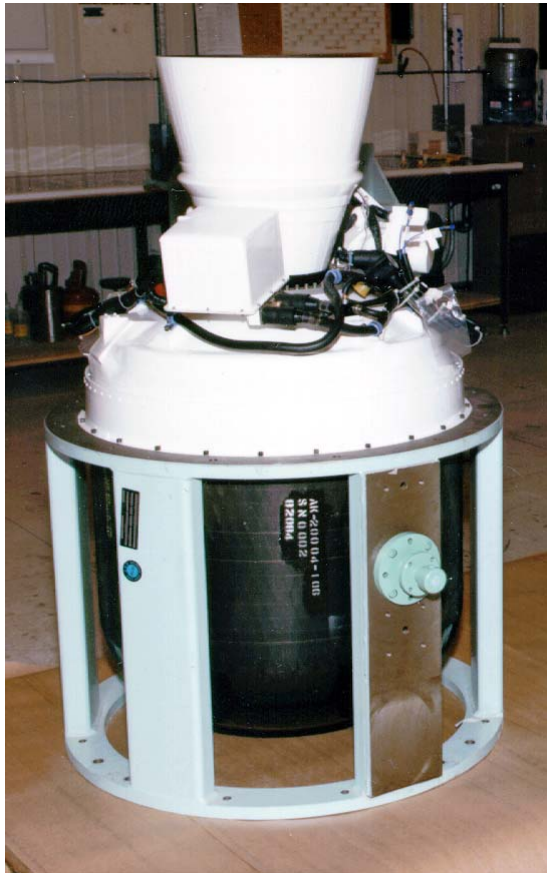


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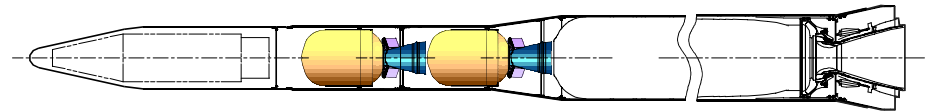
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Chase Chairs NMD Independent Review--1999

Programmatic and Technical Actions Recommended



19810-27



- **National Missile Defense (NMD) System**
 - Primary new generation anti-missile (US-wide) protection system



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Chase Serves on Various Committees

AIAA—IAF—COMSTAC

- **American Institute of Aeronautics and Astronautics — AIAA**
 - Chaired: many technical sessions
 - Authored: many technical papers
 - Chairman: Solid Rocket Technical Committee (SRTC)
 - Director: Propulsion & Energy Group
 - Member: Board of Directors
- **Int'l Astronautics Federation — IAF**
 - Member: Space Transportation Committee
 - Member: Space Propulsion Committee
 - Chaired: Many technical sessions
- **Commercial Satellite Technical Advisory Committee — COMSTAC**
 - Member



AIAA Joint Propulsion Conference

Chase: Chairman, Monterey, CA — 1993

- P&W Space Propulsion sponsored AIAA Joint Propulsion Conference: Monterey 1993
- Chase was General Chairman who (with support from other CSD staff) organized the entire conference
- Conference theme: “International Cooperation in Aerospace”
- Chase raised \$100K from 40 corporations to bring 30 scientists to the JPC from Russia and Ukraine
 - This jump-started the JPC as a major international conference
- Chase invited keynote speakers from Asian, European and US space agencies
- The conference set an attendance record



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AIAA Joint Propulsion Conference

General Pictures



Chases and Norths with
Russian visitor



Chase with group



Chase with
Chinese delegation



Chases with Greenwell



Schaeffer, Quinlan, Sinclair,
Castro and Parsley



Part of
Russian delegation



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AIAA Joint Propulsion Conference

General Pictures



Chase gives thank you dinner for support staff



Presidential suite deck



Evening dinner party at Monterey Aquarium



Chases at Monterey Aquarium



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Chase Elevated to AIAA Fellow--1999

Citation:

Outstanding contributions to the successful development of launch vehicle and upper stage solid rocket motors in support of manned space flight, satellite communications and interplanetary missions



With Louis Chênevert
and Pierre Betin (Snecma)



With Carole and
Patti Grace Smith (FAA
Associate Administrator-Space)



With Claude Bonnet,
Pierre and Alan McDonald



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Congrats From UTC's President & COO

United Technologies Corporation
United Technologies Building
Hartford, CT 06101



Karl J. Krapek
President and Chief Operating Officer

May 6, 1999

Mr. Charles A. Chase
Manager, Space Propulsion Business
Development
Pratt & Whitney Space Propulsion
P.O. Box 49028
San Jose, California 95161-9028

Dear Charles,

It was such a thrill for me to be at the Honors Night Banquet when you were named a 1999 AIAA Fellow. I know it was a wonderful night for you and your family. It was also a great night for Pratt & Whitney, as you bring great honor and recognition to your company.

You stood so proudly when introduced that I know this award means a lot to you. Thank you for working so hard and diligently for Pratt & Whitney and our industry. Once again, well done.

Best regards,

A handwritten signature in black ink, appearing to read "Karl", with a horizontal line above it.



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Chase Receives Another Patent Award



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Manager, Business Development

Space Propulsion Systems — CSD (1995 through 2003)

- Responsible for new business opportunities involving launch vehicles and space propulsion systems (solid rockets, hybrid rockets and electric propulsion systems).
- Directly involved in all space-related foreign collaborations and evaluations of potential domestic joint ventures and mergers and acquisitions
- Oversees engineering and programmatic support for new business ventures and proposal efforts



Promoting International Collaboration — China



Wang Liheng welcomes
Chase to China



With George David
in Beijing



With Al Haig
in Beijing



Visiting HEXI in
Inner Mongolia



Typical Chinese
business feast



Ron Michalak and Chuck
try some eel



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Promoting International Collaboration — Russia



With Vladimir
in 30-below Perm



Signing a Protocol
at NPO Iskra (Perm)



Choot-choot of vodka
at NPO Iskra (7:30 AM)



Working hard
at Perm Airport



Chase and Verlot agree with
NPO Iskra to proceed with pilot
study



Carole and Chuck at
Russian Federation's
Faberge exhibit (SF)

Chase — The Lecturer

- Chase talked about his and CSD's experiences to:
 - University students
 - University of Michigan
 - Stanford University
 - Naval Post Graduate School
 - AIAA SRM Short Course for young engineers
 - Kiwanis and Rotary Clubs
 - Groups of “New Hires” at CSD
 - Grammar school classes



Promoter of Young Rocketeering



Students from Fisher Middle School—Los Gatos, CA



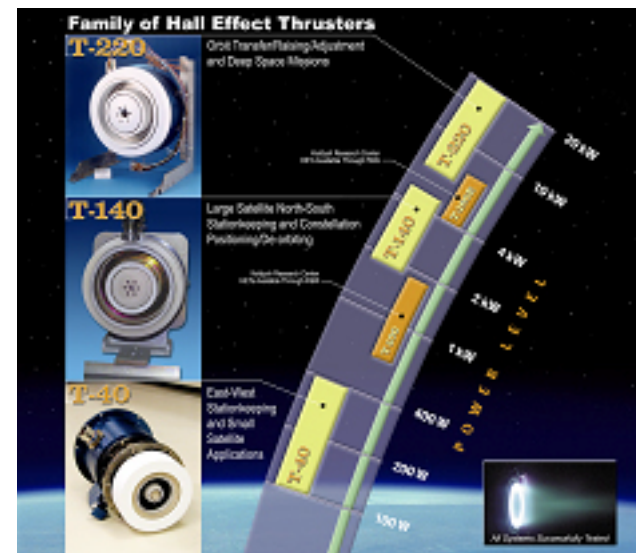
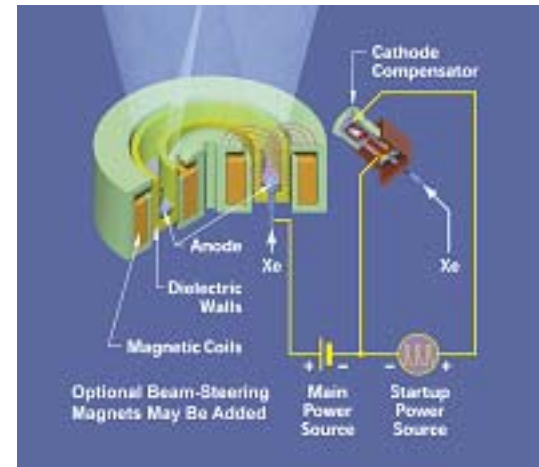
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CSD Expands into Electric Propulsion Systems

Chase Spearheaded the Team

- As part of its continuing effort to broaden the business horizons of P&W Space Propulsion, it was decided to explore opportunities in satellite propulsion. Of key interest was electric propulsion (EP)
- For two years Chase pursued the pros and cons associated with the acquisition of Space Power, Inc., a small EP company
- In July 2000 the acquisition (P&W-SP's first) was completed. Then Chase's responsibility changed to making SPI into an electric propulsion system supplier



Chase Writes “Pocket Rocket” Book



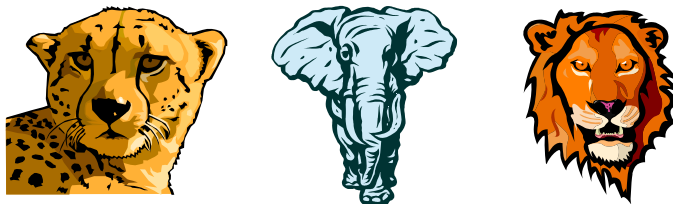
- Used as textbook at University of Alabama-Huntsville
- Used as textbook at University of Rome



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Chase's 40th Anniversary at CSD



Now that **Charles Chase** has returned from his African Safari...

Let's celebrate his 40th Anniversary at CSD!

Join us for ruminations, robusta coffee (Java), and really remarkable cake! (Realistic reproductions of his relaxing retreat may be readily available too!)

Date: Wednesday, October 2

Time: 1:00 PM

Location: Building 0010 Auditorium



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Chase Receives NASA's Stellar Award-2003

For Contributions to NASA's Space Programs

Citation: Charles A. Chase is a rocket propulsion pioneer and visionary who has been the key technical director of some of this nation's most important space propulsion programs that have met and conquered their many world record challenges. Many of his programs have allowed NASA and other US agencies to successfully achieve missions critical to better understanding our universe and protecting our homeland.



Presented Stellar award by
Astronaut Sandra Magnus



Carole and Chuck with award



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Chase Elected to IAA Full Membership-2003

For Major Rocket Propulsion Contributions



Limited to 1000 members worldwide



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Chase Becomes Program Manager--2003

— Space Programs

Internal Correspondence



December 22, 2003

Appointment of Mr. Charles A. Chase as Program Manager--Space Programs

I am pleased to announce the appointment of Charles Chase to the position of Program Manager for all Space Programs at Pratt & Whitney-Space Propulsion's San Jose Site, effective December 22, 2003. As my direct report, Chase will have overall management responsibility for all solid propellant space programs, especially the Booster Separation Motor (BSM) program and its support of the Shuttle return to flight (RTF). Chase will also oversee all P&W efforts associated with electric propulsion systems. His duties will include interfacing with customers and in-house organizations; preparing proposals; and managing costs, schedules, and subcontracts.

Darryl Bramlette will report to Chase and will continue to lead the Pratt & Whitney BSM Igniter Team in support of the RTF. Darryl, as Integration & Launch Support Program Manager, will also continue to support the following programs: Inertial Upper Stage (IUS), Athena, GEMA, NEA (San Jose) and the Solid Rocket Motor Technical Support Program

Chase has over 41 years of engineering and management experience at P&W's San Jose Site. His responsibilities have included: Chief of Solid Rocket Advanced Design, Original Chief Engineer on the BSM and Inertial Upper Stage (IUS) programs and later Chief Engineer for all Space Programs. His most recent assignment: Business Development Manager--Space, included leading the acquisition of an Electric Propulsion company to expand P&W's propulsion capabilities.

Chase received a BS and MS Degree in Aero/Astro Engineering from the University of Michigan, and also has a post-graduate Degree of Advanced Engineering (Aero/Astro) from Stanford University.

Chase has been very active in the American Institute of Aeronautics & Astronautics (AIAA) where he was Chair of the Solid Rocket Technical Committee, Director of all Propulsion and served on the AIAA Board of Directors. He is an AIAA Fellow. Also he is on the FAA COMSTAC Committee, the International Astronautics Federation's (IAF) Space Propulsion & Space Transportation Committees and was recently awarded NASA's Stellar Award and was elected to full membership in the International Academy of Astronautics (IAA).

Please join me in wishing Charles Chase every success in his challenging new assignment.

Mark Mounsey
General Manager
P&W Space Propulsion - San Jose



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P&W Space Propulsion
Chemical Systems Division

Chase Receives NASA's Leadership Award-2004

From NASA Headquarters — for Directing BSM Program



Chase with Shuttle/ISS astronaut Dan Bursch and
Gen. Mike Kostelnik: Deputy Assoc Administrator--ISS & Shuttle



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Concluding Remarks

- I have been most fortunate to have worked with some of the propulsion world's brightest engineers and scientists. Through our collective efforts we have conquered significant challenges. Together we have contributed to some of the most important space missions in history.
- More importantly, however, I have been blessed to work with some highly talented and truly wonderful people at CSD. CSD has always had the trait of being a family where we supported each other when the need arose. These special people along with our many spectacular accomplishments have created an endless collection of great memories.





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P&W Space Propulsion



**Chemical Systems
Division**

