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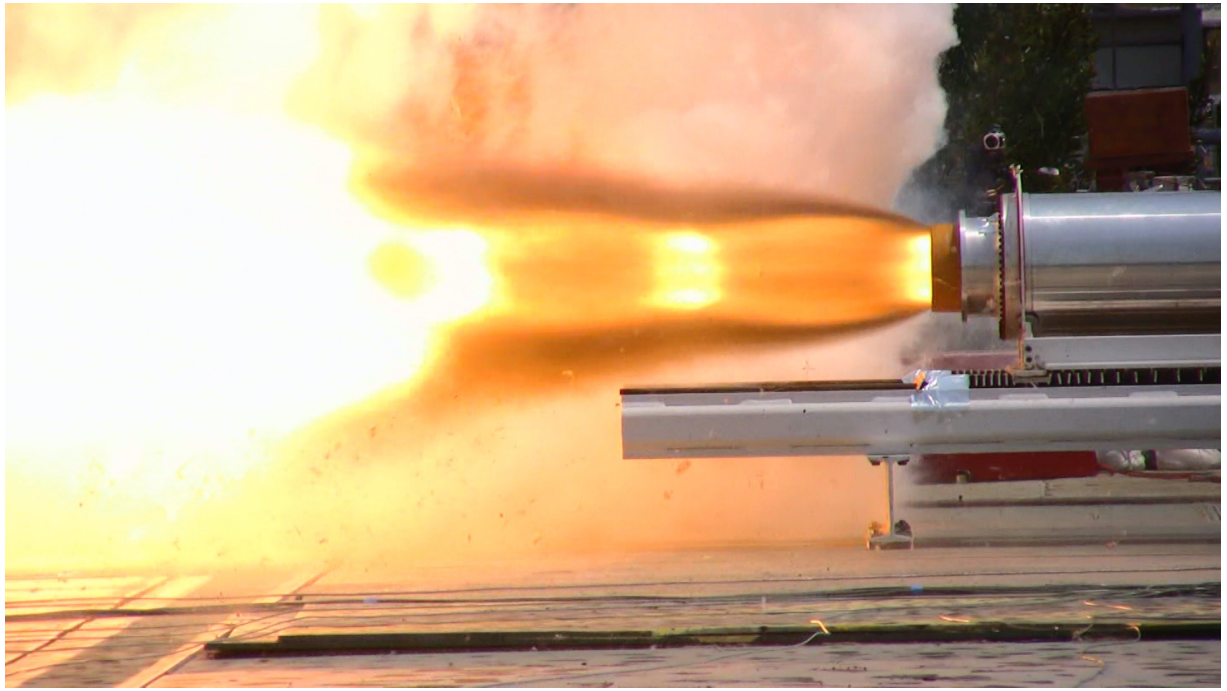
AA283

Aircraft and Rocket Propulsion – Spring 2023 - 2024

Course Introduction



Instructor – Brian J. Cantwell, 250A Durand
Location – History Corner 200 – 02
Class Hours – T Th 12:00 – 1:20
Office Hours – T Th 1:30 – 3:00 and by appointment

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Exam / Homework / Grading Policies

Exam policy - Exams are in taken in class during the assigned time. Students are permitted to bring books, notes and tables as well as a graphing calculator to the exams. Laptops are allowed to access course notes. Use of the internet is not allowed. Although Matlab and Mathematica can be used to work exam problems, you must show your work on the exam including equations, methods and assumptions so that the graders can fully understand your approach. As a guide, your exam solutions must show detail comparable to your homework solutions.

Homework - Homework problems will be assigned each tuesday and will be due the following tuesday. The understanding gained through solving problems is absolutely crucial to learning the course subject matter. You are not expected to work on homeworks in total isolation; seek out your peers, the course assistants and the instructor when you need help on the problems. This is a fundamental part of the learning experience. Just be sure that whatever you hand in, is your own work. Homeworks that are turned in by 5:00 PM on the date due will be carefully examined, graded and returned. There is a considerable effort required to grade the homeworks. Please be considerate of the course assistants and make every effort to turn your homework in on time. Late homeworks will not be graded. They will be assigned up to 3/5 credit depending on effort and returned without examination.

Grading - Homework - 20% Exam 1 - 40% Exam 2 - 40%

Exam dates
Exam 1 - Thursday, May 2, in class 12:00 to 1:20
Exam 2 - Thursday, May 30, in class 12:00 to 1:20

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Course Reference Material

Required Text: Course Reader, *Aircraft and Rocket Propulsion* – These are my course notes and can be downloaded in pdf format from my web site.

https://web.stanford.edu/~cantwell/

Recommended References

Hill and Peterson, *Mech. and Thermo. of Propulsion*, 2nd Edition, Addison-Wesley

Kerrebrock, *Aircraft Engines and Gas Turbines*, MIT Press.

Mattingly, *Elements of Gas Turbine Propulsion* Mc Graw-Hill

Oates, G., *Aerotherm. of Gas Turbine and Rocket Propulsion*-AIAA Education Series.

Shapiro, *The Dynamics and Thermodynamics of Comp. Fluid Flow*, Ronald Press.

Sutton, G.S. *Rocket Propulsion Elements*, Sixth Edition, Wiley Interscience.

Ashley Chandler Karp, Elizabeth Therese Jens, *Hybrid Rocket Propulsion Design Handbook*, Academic Press 2024

Resources

e-Resources – If you need access to journal articles through the Stanford system this link, https://library.stanford.edu/using/connecting-e-resources, will help you set that up on your home computer.

Course material – Materials for all my courses are available at my website at https://web.stanford.edu/~cantwell/. The folder *Course Material for AA283* includes a folder containing a bookmarked pdf of the course text, *Aircraft and Rocket Propulsion*, a folder where pdfs of the lectures will be posted a day or so before the lecture, and a folder where homework assignments will be posted. In addition, selected papers related to the course material are also included in a resources folder. Videos of the lectures will be placed on the AA283 site on CANVAS.

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Course Reader Contents

AIRCRAFT GAS TURBINES
Chapter 1 – Aircraft Drag and Propulsion Thermodynamics
Chapter 2 - Engine Performance Parameters
Chapter 3 - The Ramjet Cycle
Chapter 4 - The Turbojet Cycle
Chapter 5 - The Turbofan Cycle
Chapter 6 - The Turboprop Cycle

ROCKET PROPULSION
Chapter 7 - Rocket Performance
Chapter 8 - Multistage Rockets
Chapter 9 - Thermodynamics of Reacting Mixtures
Chapter 10 - Solid Propellant Rockets
Chapter 11 - Hybrid Rockets
Appendix A - Elements of Thermochemistry
Appendix B - Selected JANNAF Data

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Useful Web Sites - pictures and videos

This is my web site where the AA 283 notes can be found in pdf format along with pdfs of the lectures and homework assignments and selected resources.

http://www.stanford.edu/~cantwell/

This Virginia Tech web site has a useful app for calculating the properties of a one-dimensional compressible flow as well as several other apps.

http://www.engapplets.vt.edu

Lots of interesting flow pictures.

http://www.efluids.com/efluids/pages/gallery.htm

This MIT site has the Fluid Mechanics Films produced for the National Science Foundation in the 1960's available in streaming video. Highly recommended.

http://web.mit.edu/fluids/www/Shapiro/ncfmf.html

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Useful Web Sites – Software for Combustion Calculations

http://www.grc.nasa.gov/WWW/CEAWeb/ceaHome.htm

This is a NASA Glenn web site where you can access the application CEA (CHEMICAL EQUILIBRIUM WITH APPLICATIONS).

http://cearun.grc.nasa.gov

This is a web-based interface for running CEA. You need a browser with cookies and Javascript enabled. Any problems with this site should be reported to mark.leader@nasa.gov.

https://www.grc.nasa.gov/WWW/CEAWeb/ceaThermoBuild.htm

This link takes you to a site with an application called ThermoBuild which is an interactive tool that allows you to access the NASA Glenn thermodynamic database to select species and to obtain tables of thermodynamic properties and data sets for use in CEA, or any other computer program.

http://software.lpre.de/index.htm

This link takes you to a site with a downloadable (for a price) application called RPA - Tool for Rocket Propulsion Analysis. The capabilities are very similar to CEA.

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Useful Web Sites – Khan Academy short video lectures

One of the most interesting developments in recent years has been the creation of new, free websites dedicated to online teaching. Perhaps the best of these is the amazingly extensive set of lectures put up by Sal Khan who lives in Los Altos just south of Stanford. While there are really no lectures on the site directly connected to compressible flow, there are several on calculus and thermodynamics that might be useful.

Links to a few suggested lectures are below. They typically run ten minutes or less. I am suggesting these as a means of review if you feel you are rusty on these subjects.

Integrating Factors
http://www.khanacademy.org/video/integrating-factors-1?playlist=Differential%20Equations

Second Order differential Equations
http://www.khanacademy.org/video/2nd-order-linear-homogeneous-differential-equations-1?playlist=Differential%20Equations

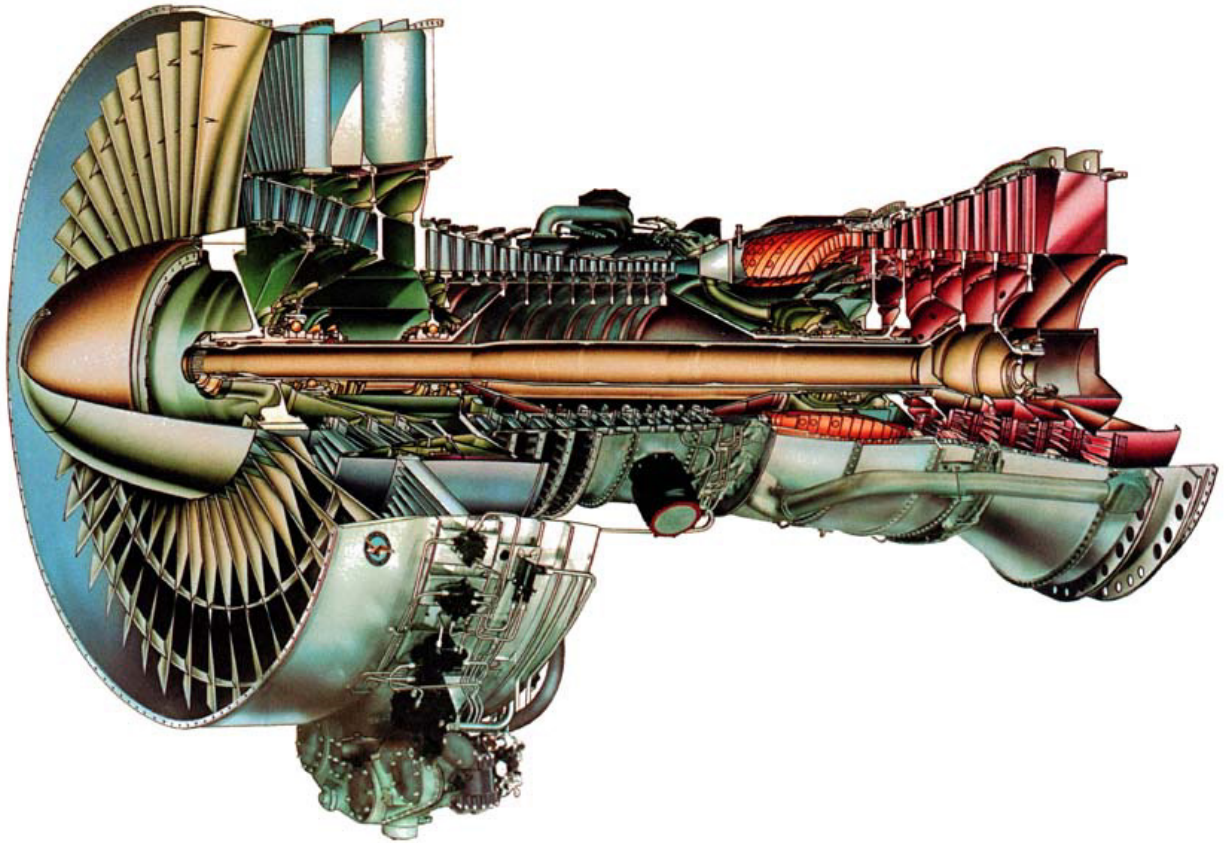
Carnot Cycle
http://www.khanacademy.org/video/carnot-cycle-and-carnot-engine?playlist=Chemistry

Enthalpy
http://www.khanacademy.org/video/enthalpy?playlist=Chemistry

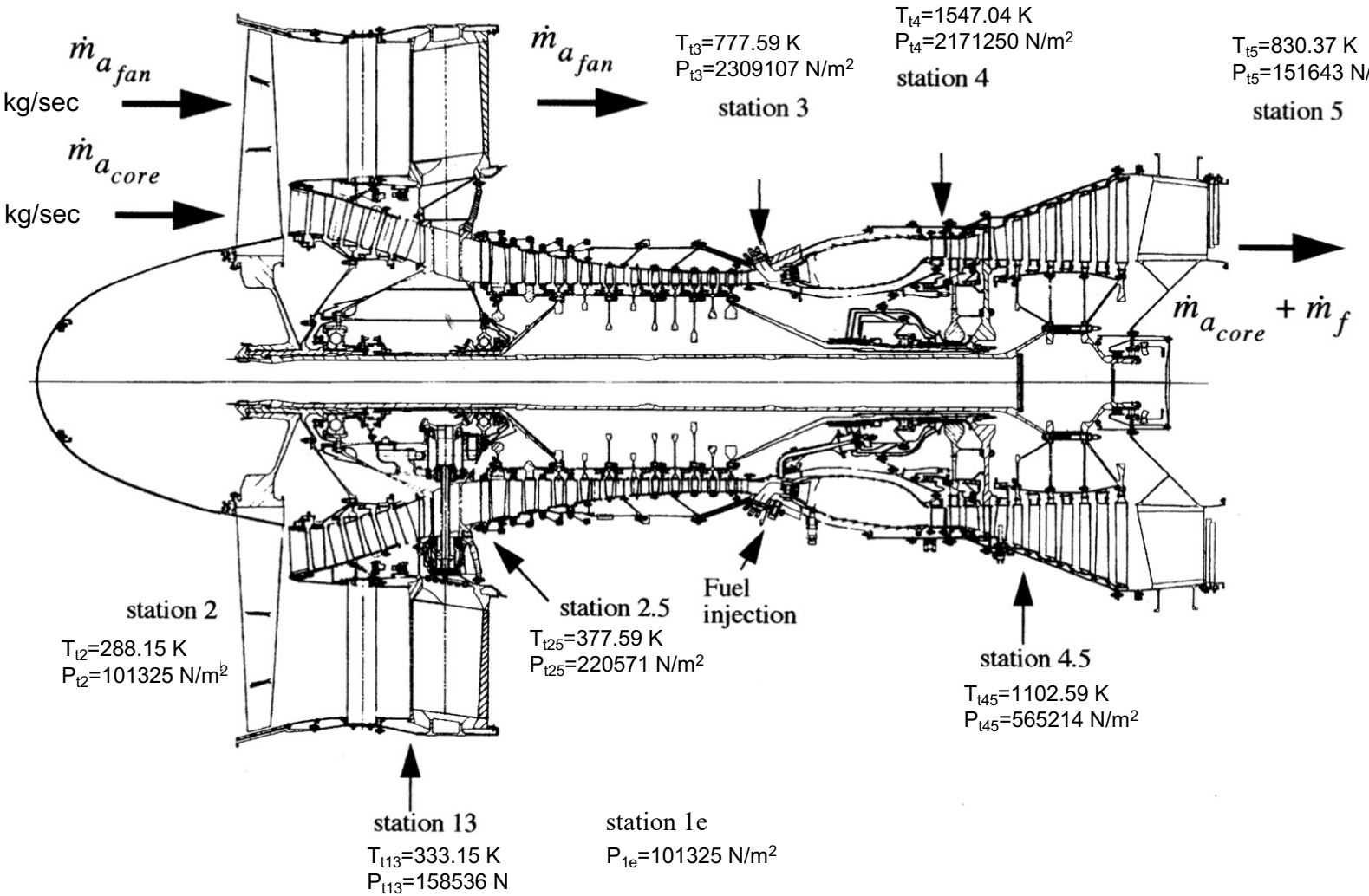
Thermodynamic Entropy Definition, Clarification
http://www.khanacademy.org/video/thermodynamic-entropy-definition-clarification?playlist=Chemistry

Pratt and Whitney JT9D

JT9D-20 TURBOFAN ENGINE



JT9D - 7



Fan diameter=2.372 m

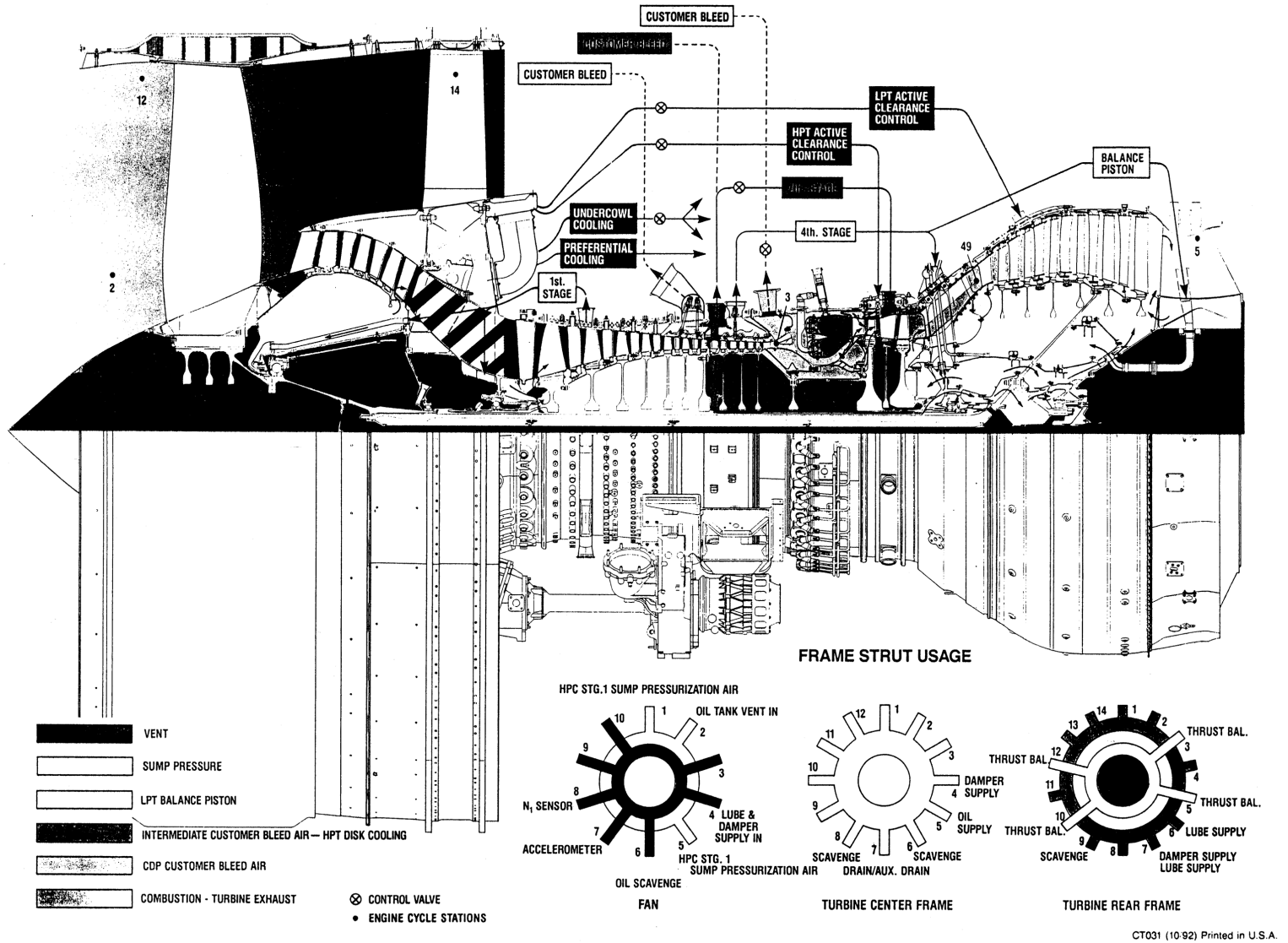
spinner diameter=0.917 m

N1=3750 rpm

N2=8000 rpm

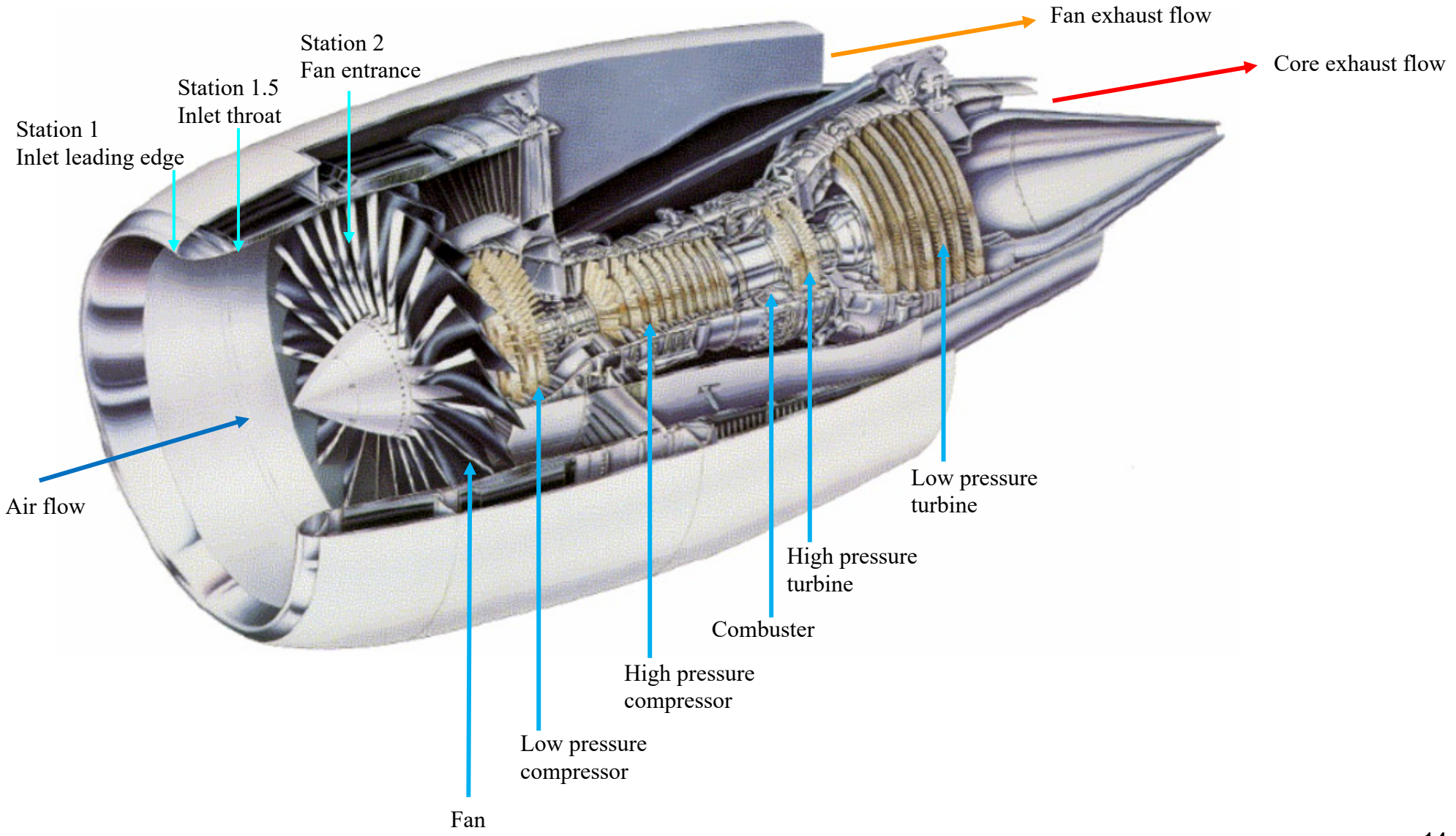
General Electric GE 90

GE 90 ENGINE AIRFLOW

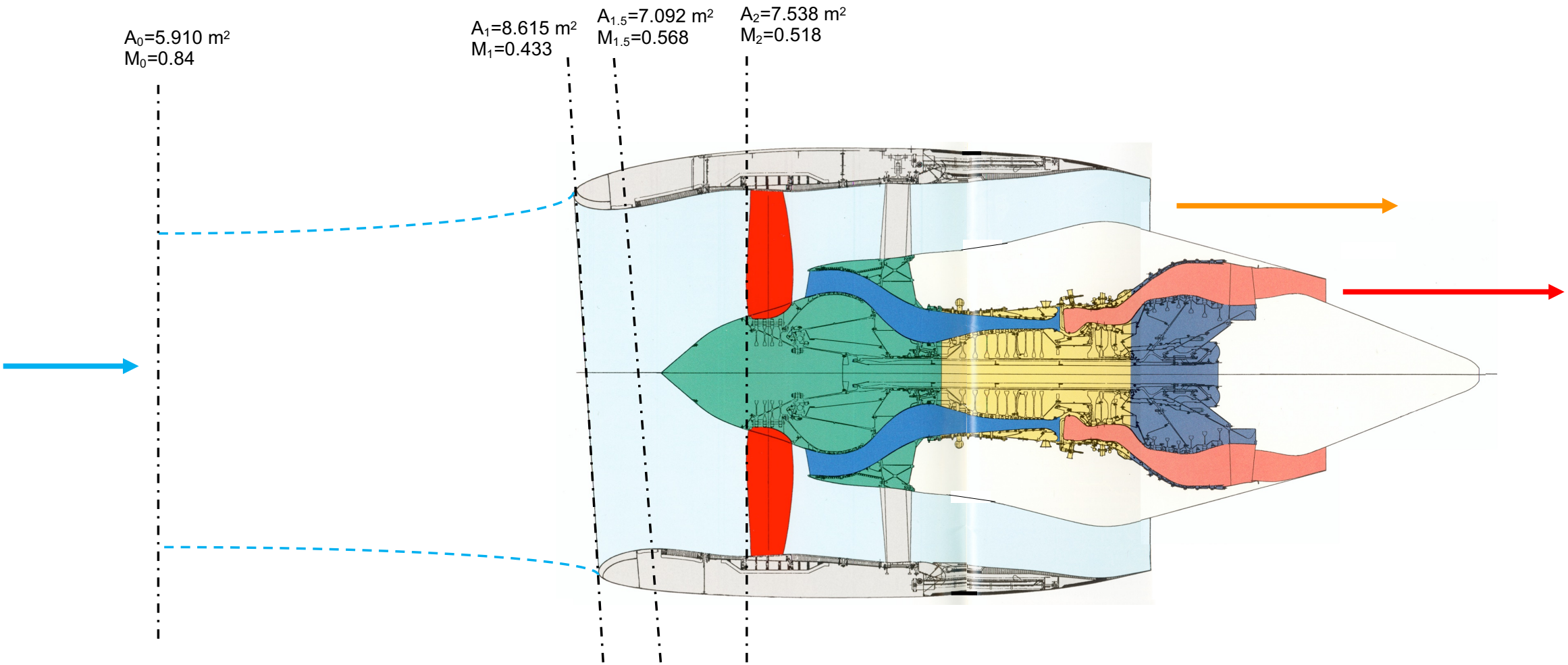


CT031 (10·92) Printed in U.S.A.

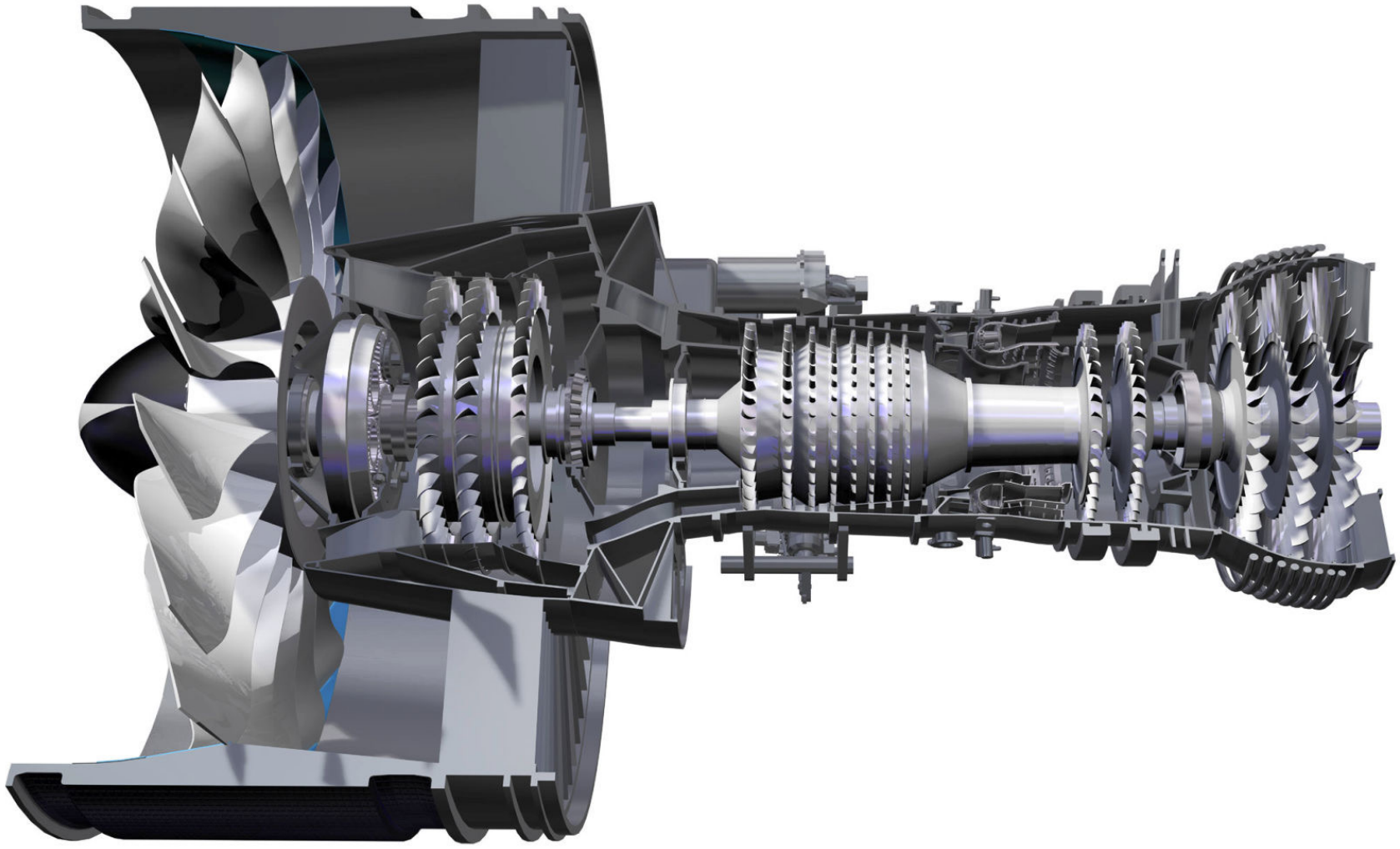
General Electric GE 90 Nomenclature



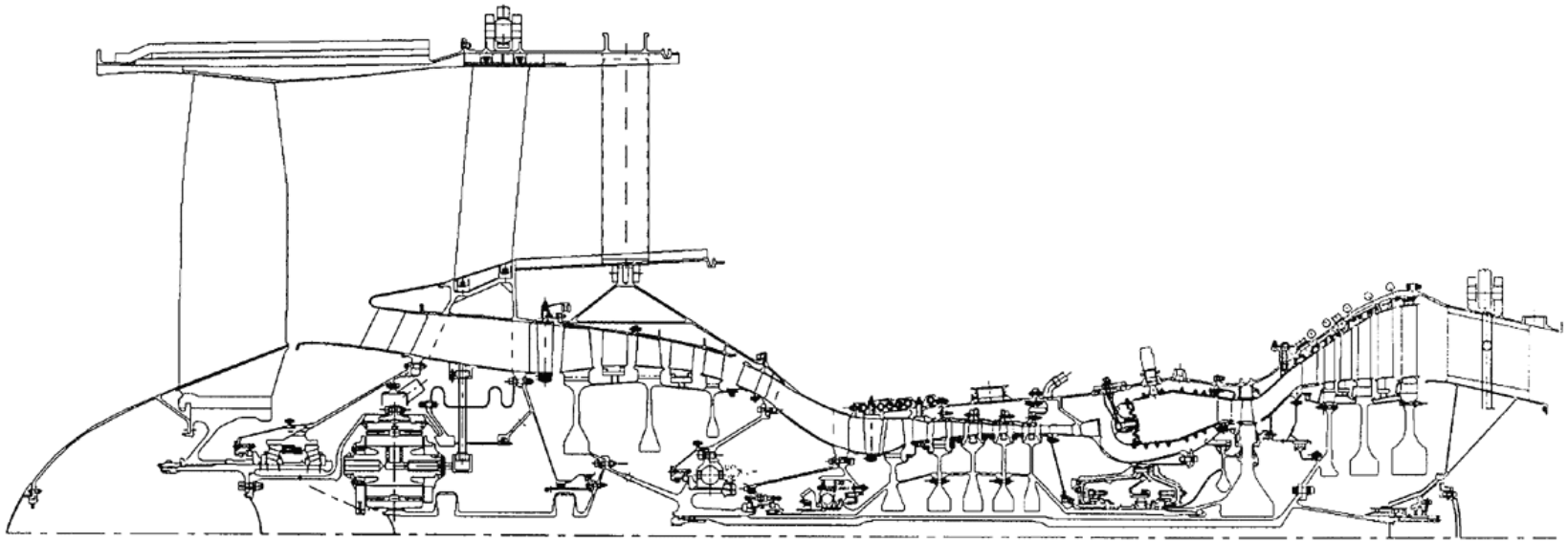
GE 90 Flowpath at cruise

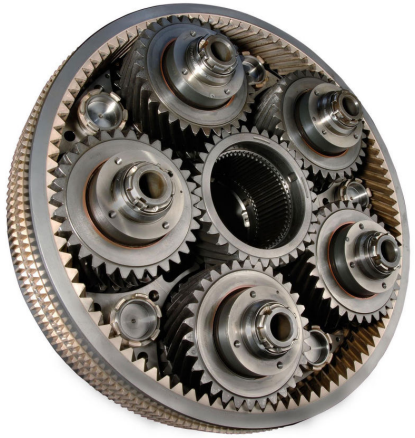


Pratt and Whitney Geared Turbofan

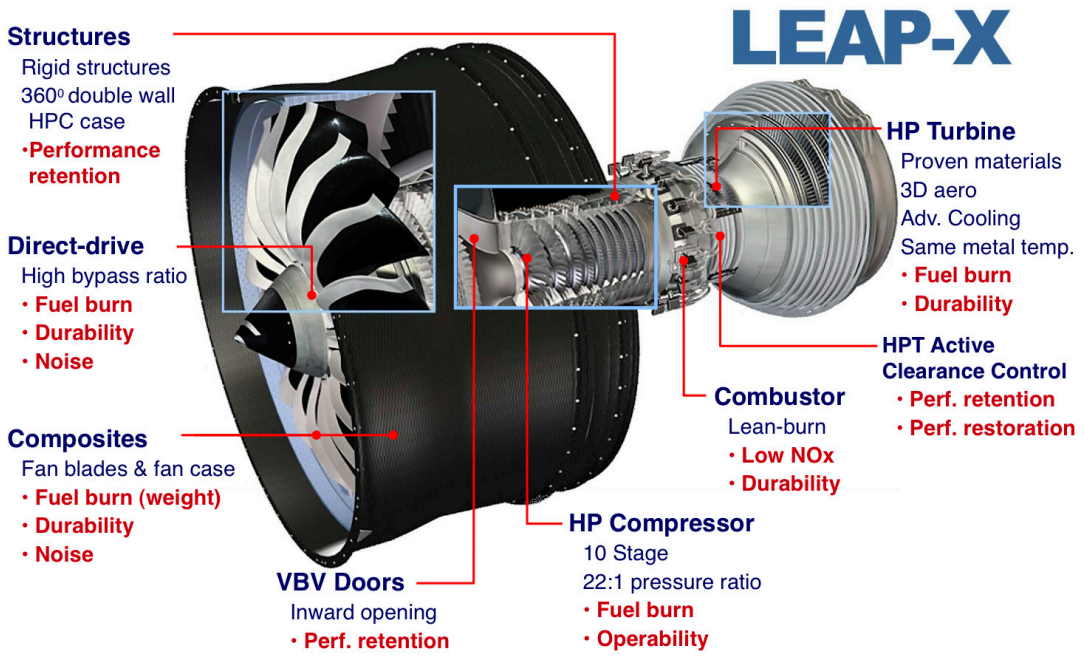


PW Geared Turbofan - cross section

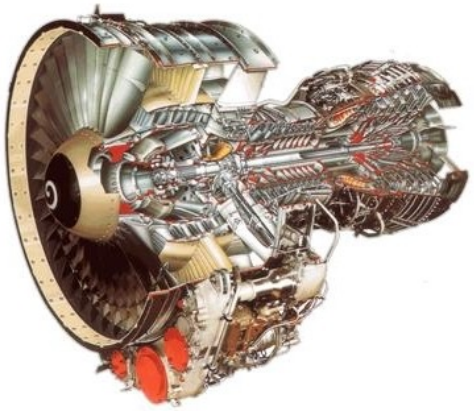


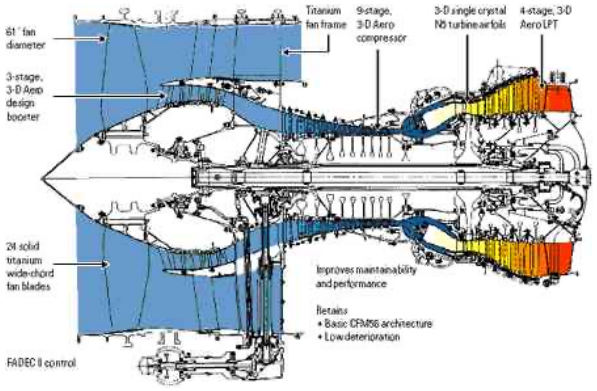


CFM LEAP-X



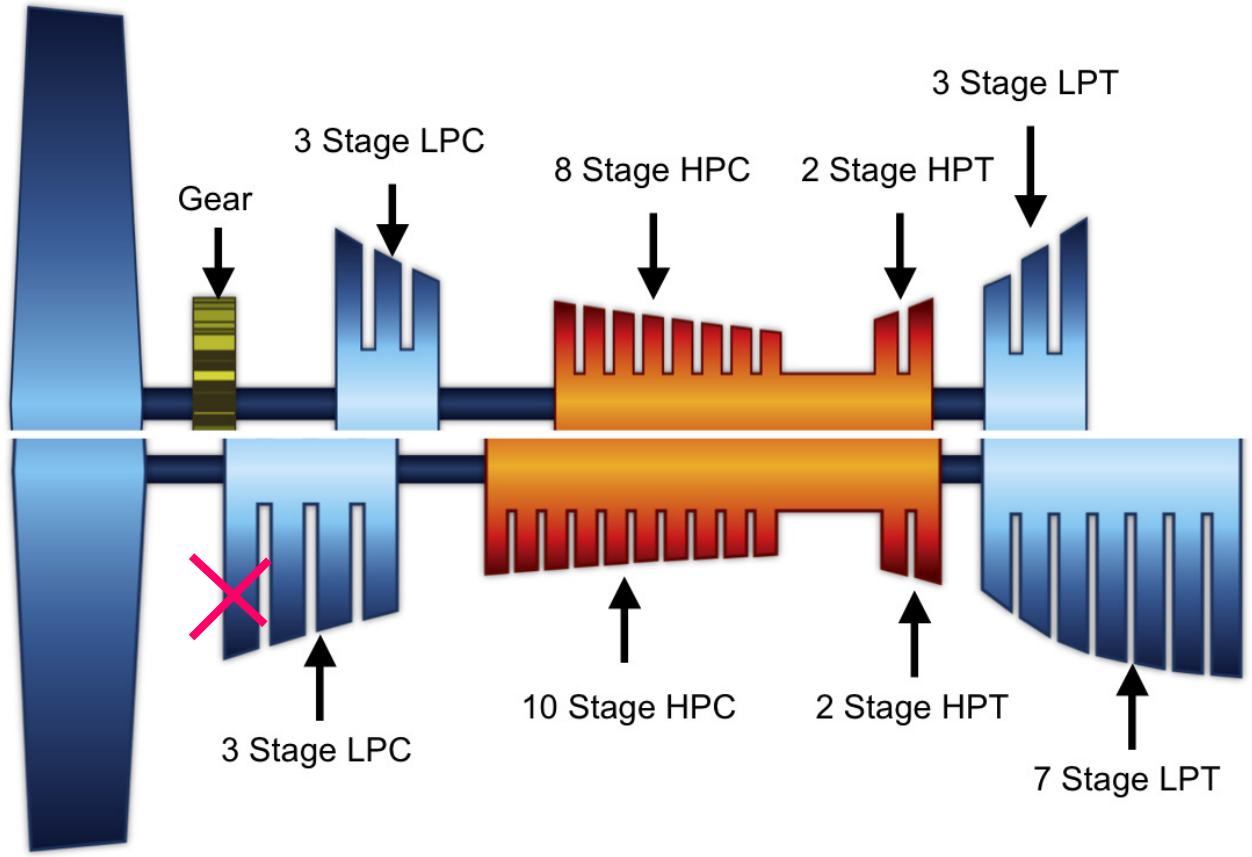
Legacy CFM-56





Comparison

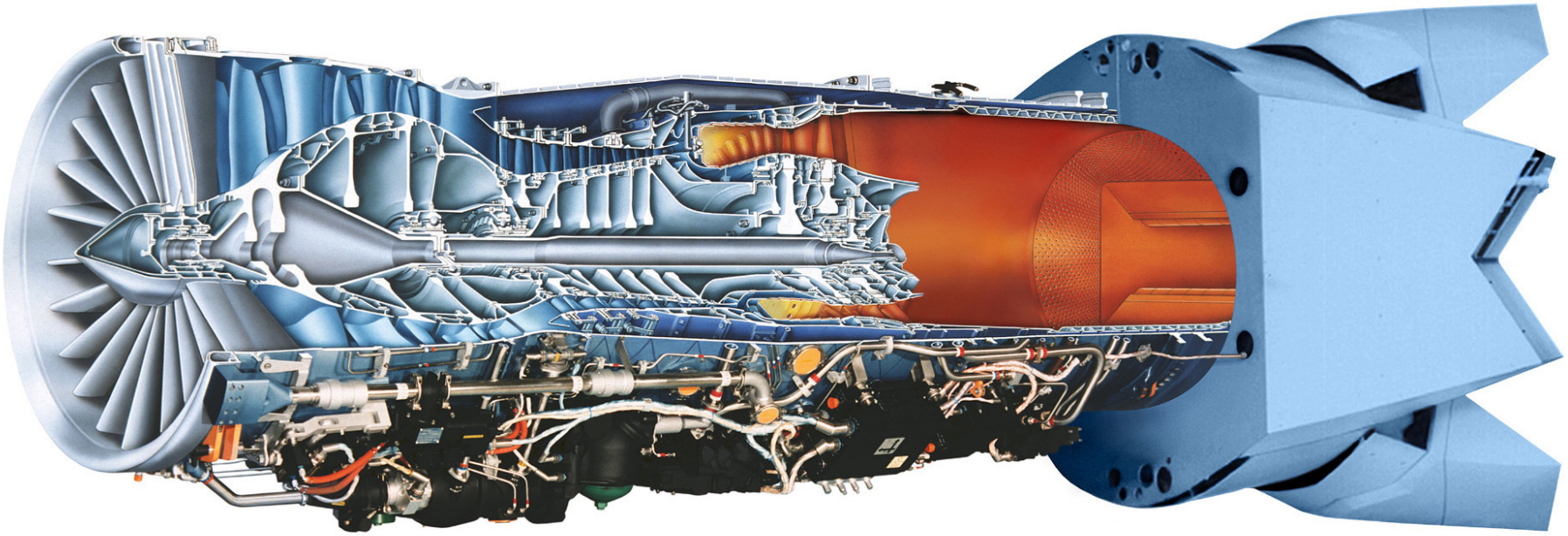
PW1100G



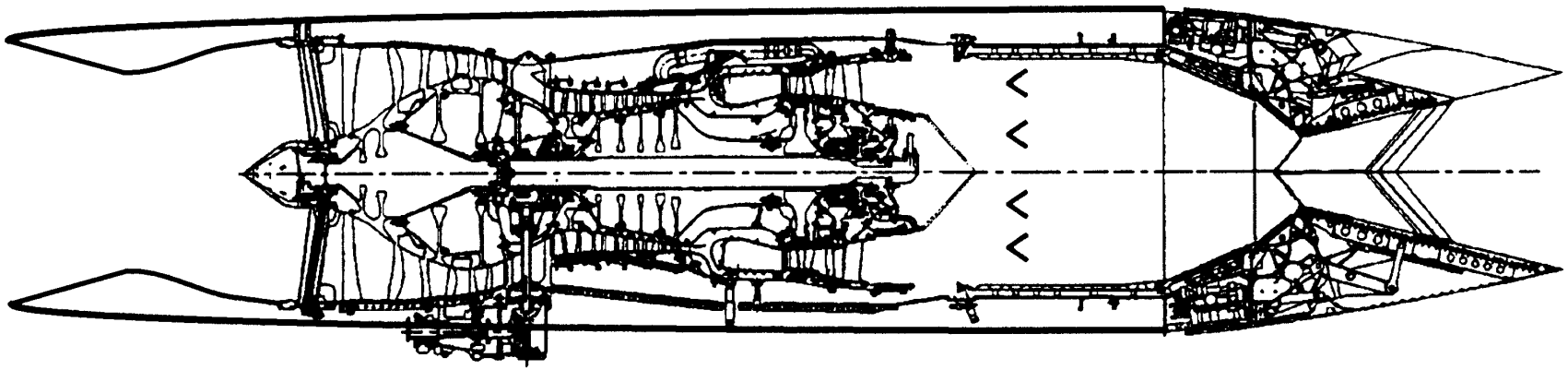
LEAP

Aircraft – A320 neo, B737 MAX

Pratt and Whitney F119

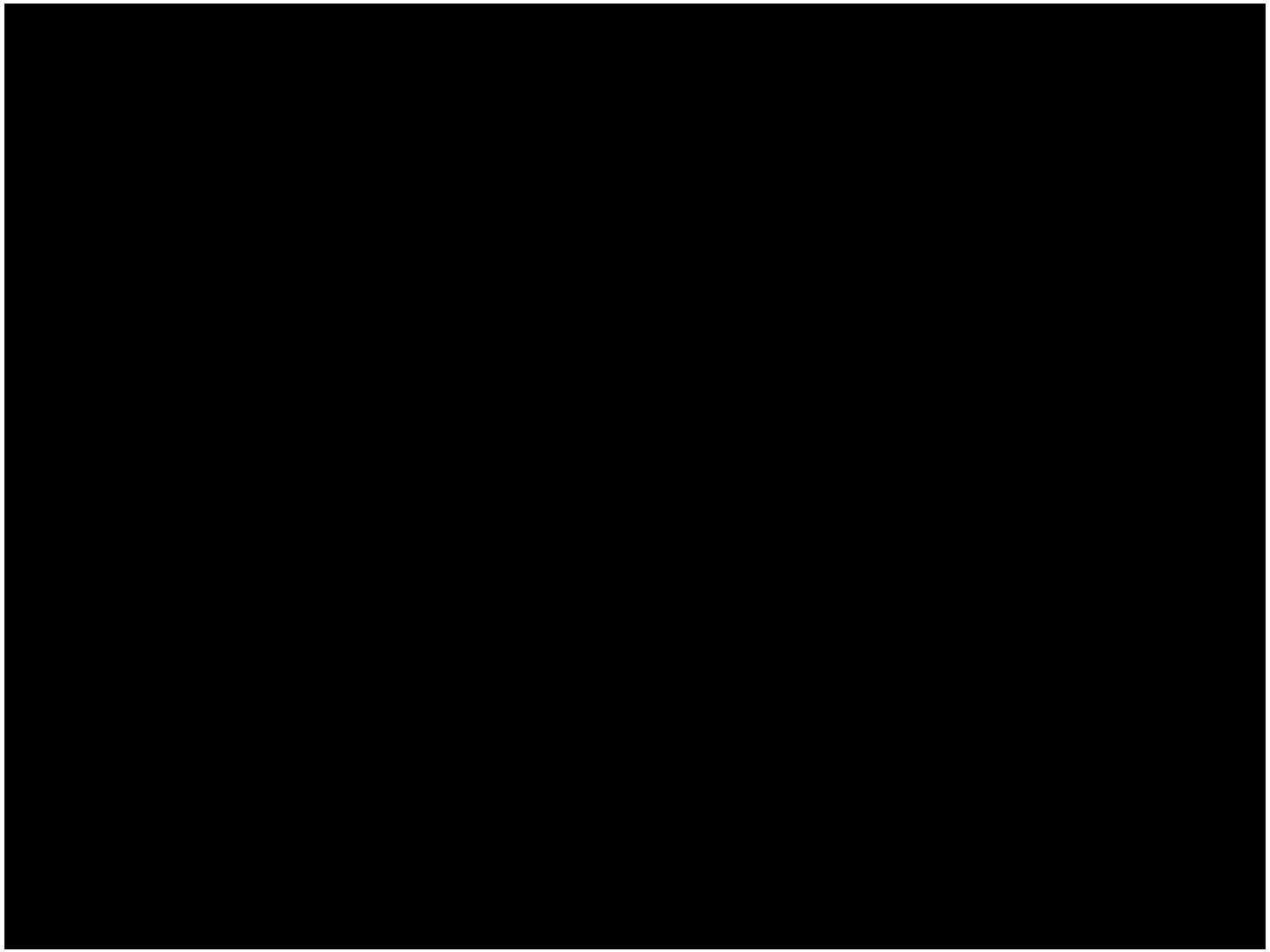


Pratt and Whitney F119

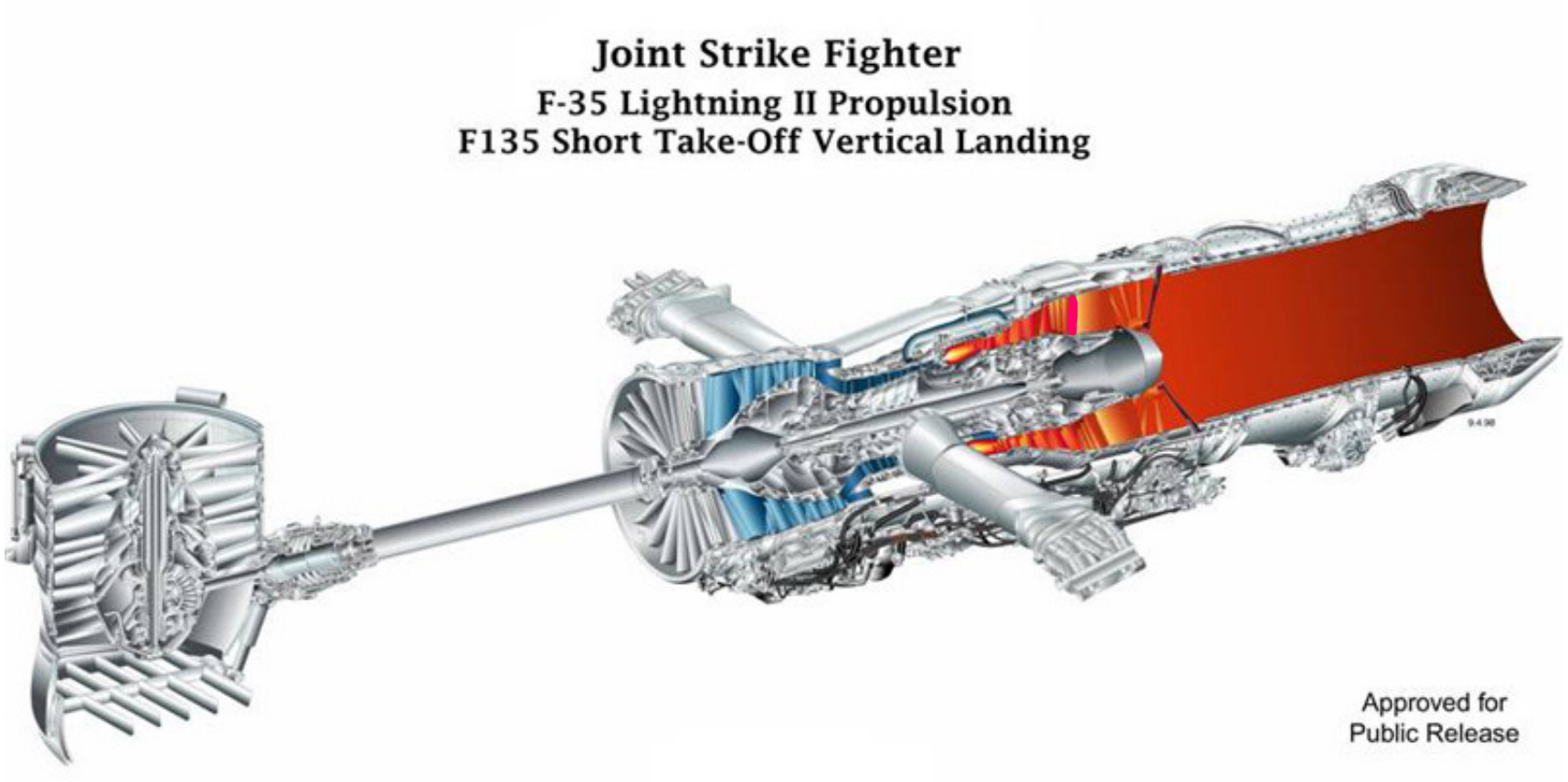


2-D Supersonic Nozzles:
The US Air Force's new fighter the F-22

Video of the vectored nozzle used on the F-22.



Pratt and Whitney F135




Rolls-Royce LiftSystem®
Providing STOVL capability for the F-35B Joint Strike Fighter
Rolls-Royce

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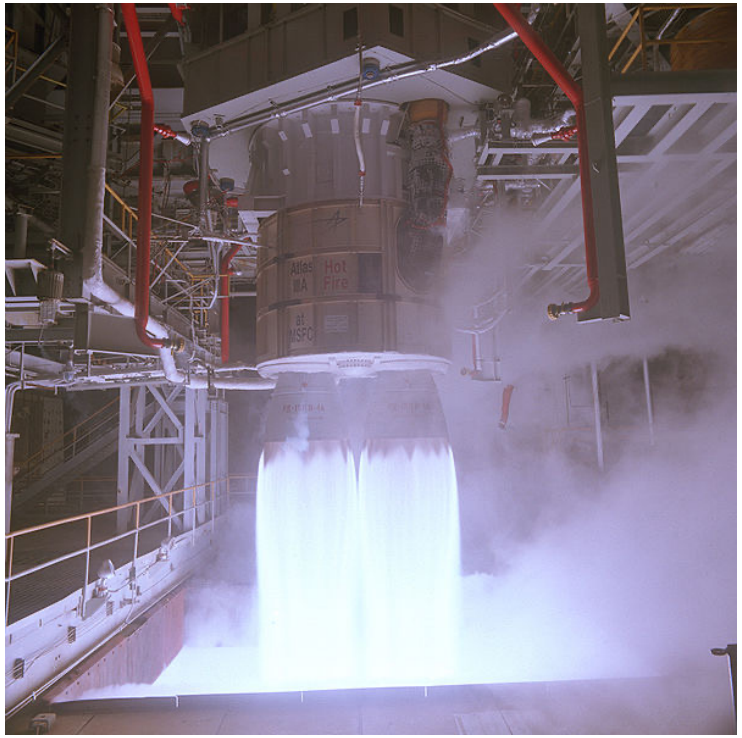
Saturn V - F1 Engine


RD-180
Pratt & Whitney Rocketdyne
Pratt & Whitney
A United Technologies Company



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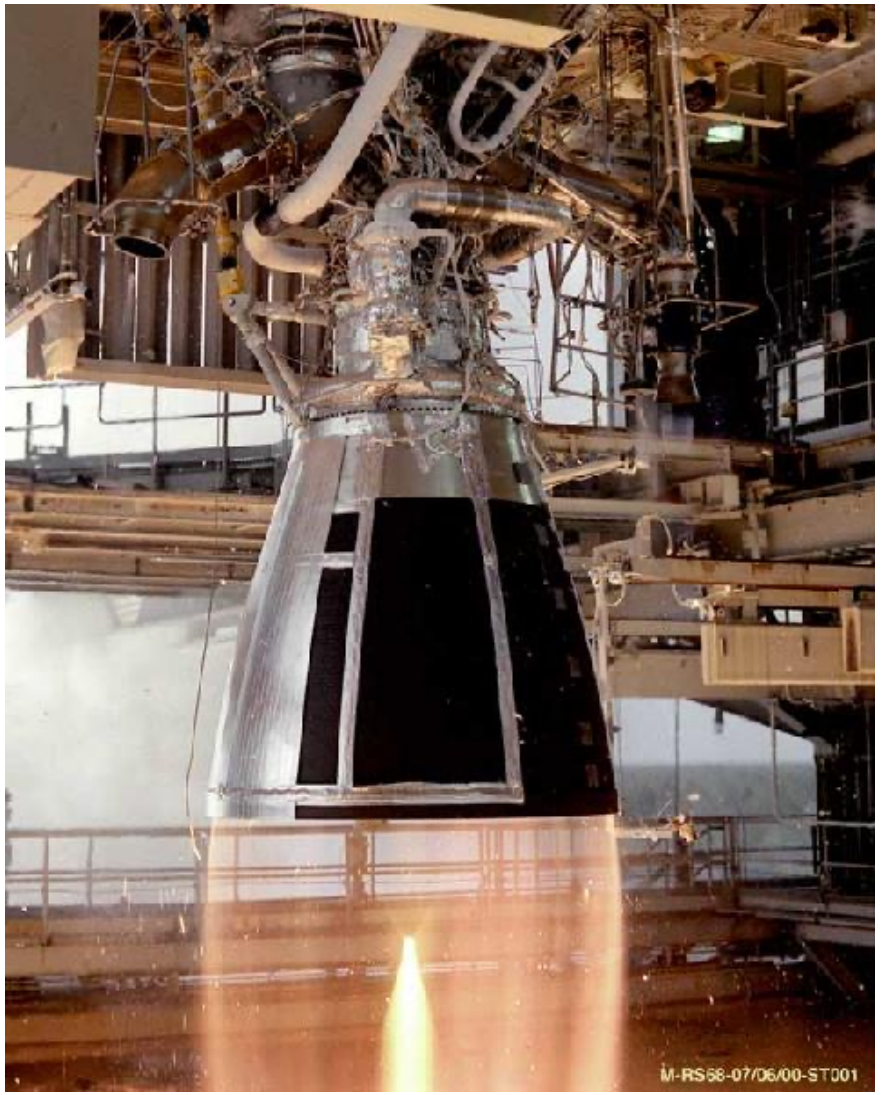
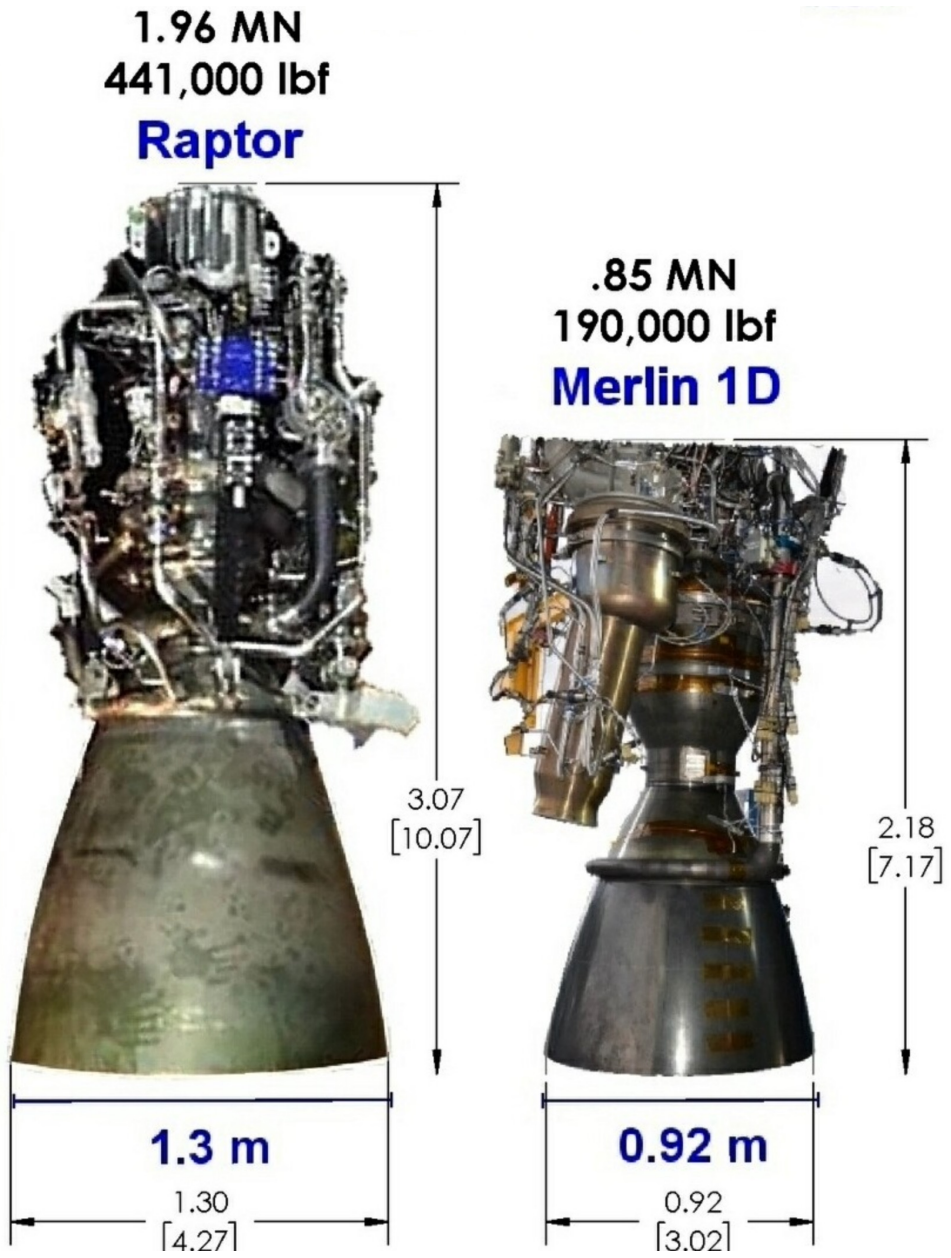
Space Shuttle Main Engine

Pratt and Whitney RS 68

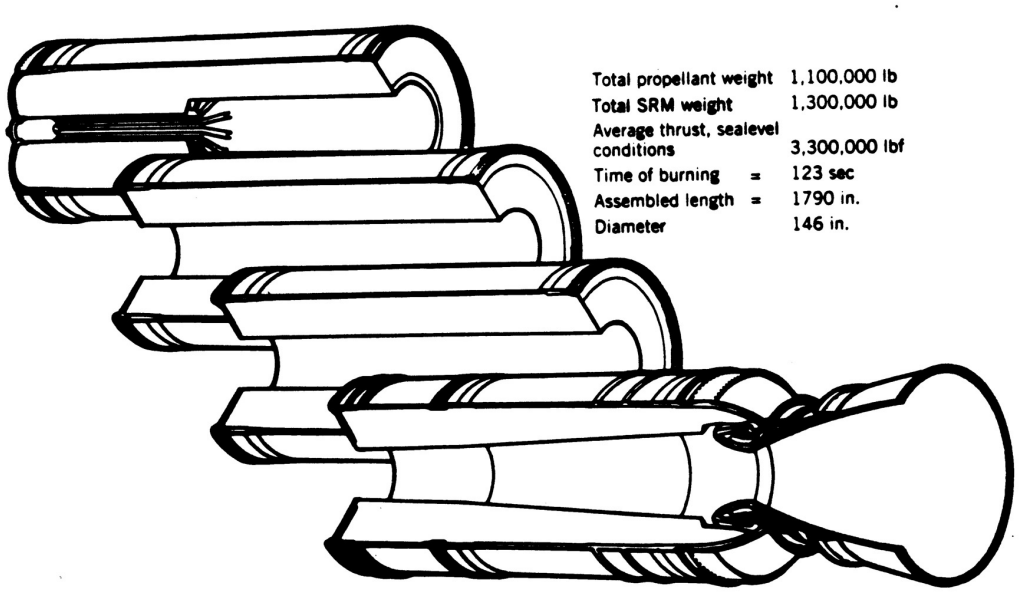


SpaceX Merlin and Raptor Engines

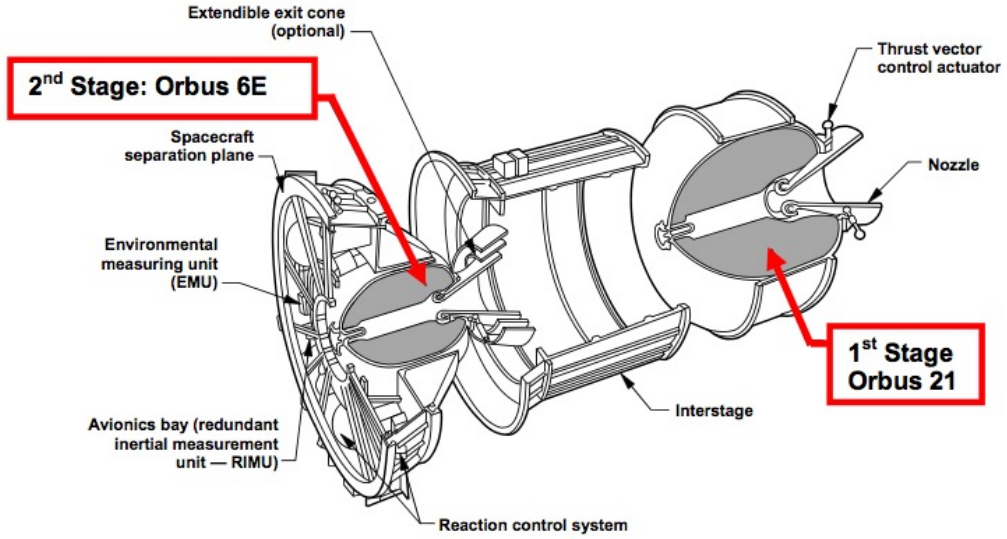


Falcon 9

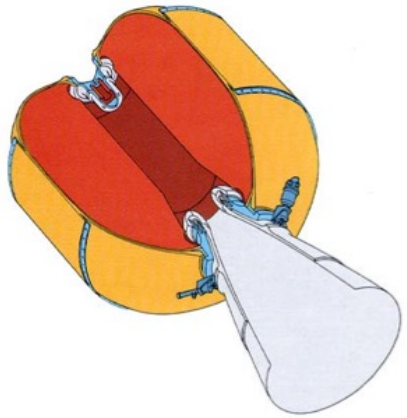
Space Shuttle Solid Rocket Booster



Boeing – CSD Inertial Upper Stage

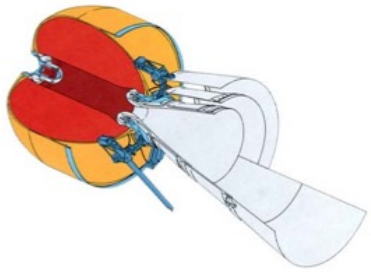


Air Force/NASA IUS, built by Boeing, a 2-Stage Space Vehicle using CSD's Orbus 21 and Orbus 6E Solid Propellant Rockets. It was Configured to Fly off both the Shuttle and Titan Launch Vehicles



Orbus 21: IUS 1st Stage

Diameter = 92-in
Wp = 21,400-lb



Orbus 6E: IUS 2nd Stage

Diameter = 63-in
Wp = 6,000-lb

Hybrid Rocket Motor Test at NASA Ames