GO BEYOND

Technical Evolution Of Fighter Engine Propulsion In The IAF: Prepared for 16th Jet Engines Symposium, Technion University

TOM PRETE, VP ENGINEERING, MILITARY ENGINES, PRATT & WHITNEY| NOVEMBER 2017

Photo Credit: Israeli Armed Forces (IAF)

Introductions

Tom Prete

VP, Engineering
Military Engines

Pratt & Whitney

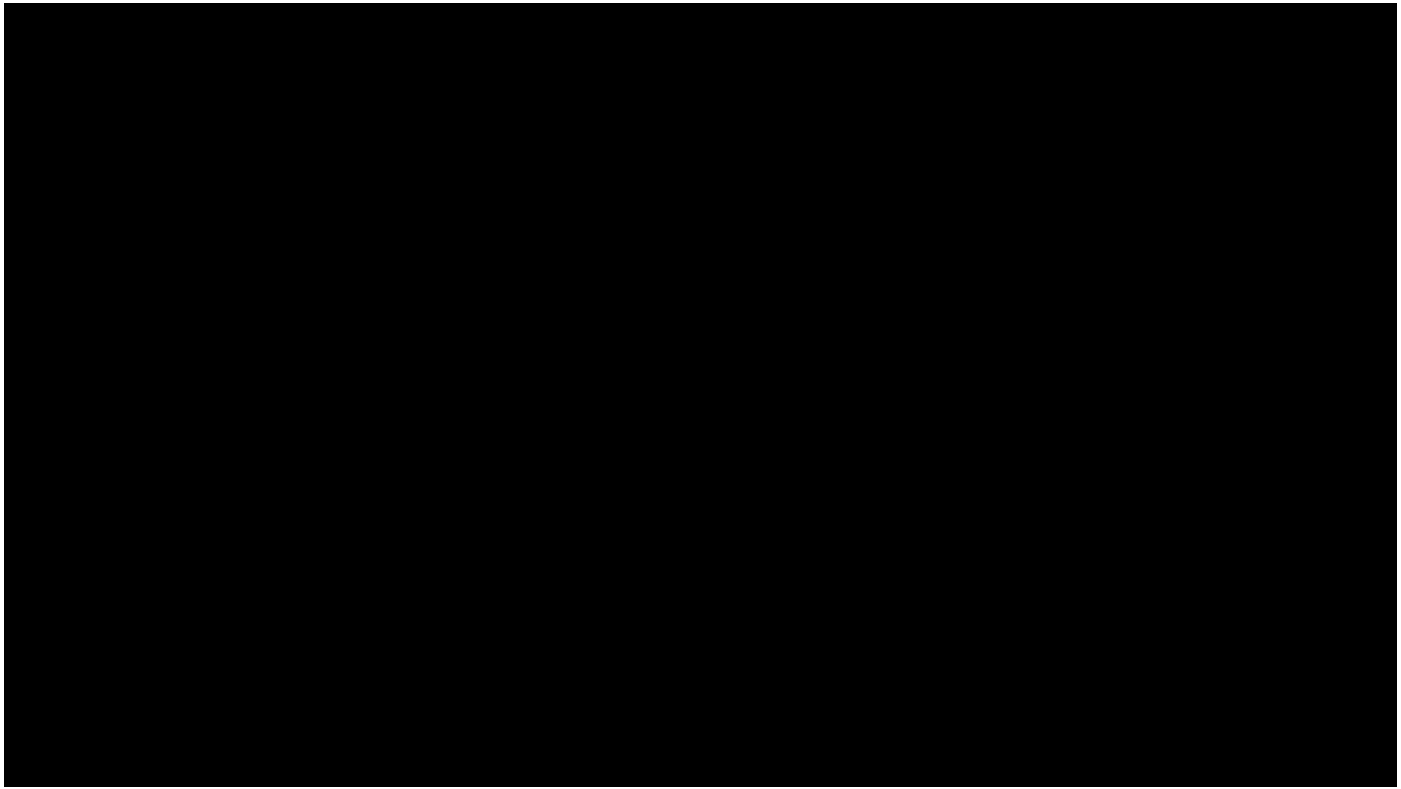
32 years in industry
28 years @ Pratt & Whitney

Broad leadership experience in design and manufacturing module centers, aftermarket and engineering organizations

BSME and MBA from University of Connecticut
MSME from Rensselaer Polytechnic Institute

Photo credit: Dane Wiedmann

Pratt & Whitney's Long History In Military Engines..



Video Credit: Pratt & Whitney

…and deep partnership with IAF

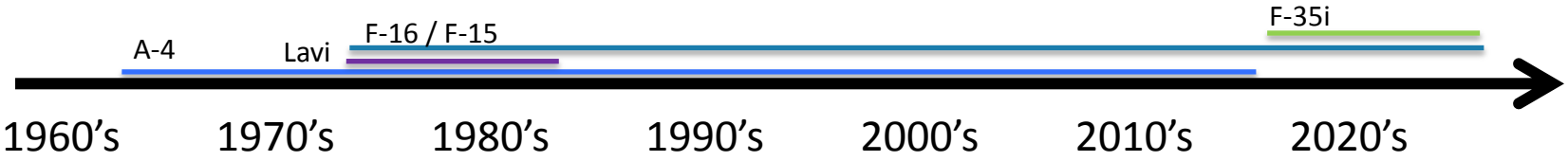

Photo Credit: Bill Fauth


Photo Credit: Pratt and Whitney


Photo Credit: Israeli Armed Forces (IAF)


Photo Credit: USAF


Photo Credit: Israeli Armed Forces (IAF)



Pratt & Whitney's Modern Portfolio

MILITARY ENGINES

Today, over 6,500 Pratt & Whitney military engines are in service with 34 armed forces worldwide, setting new standards for performance and dependability.

Photo Credits: Pratt and Whitney

F100 Engine

F117 Engine

F135 Engine

T900 Engine

*In Development under ATEC Joint Venture. Competing in an Army procurement to re-engine Blackhawk and Apache helicopters

Discussion Approach

Basics

Mission understanding

Art of design

Photo credit: Dane Wiedmann

The Basics

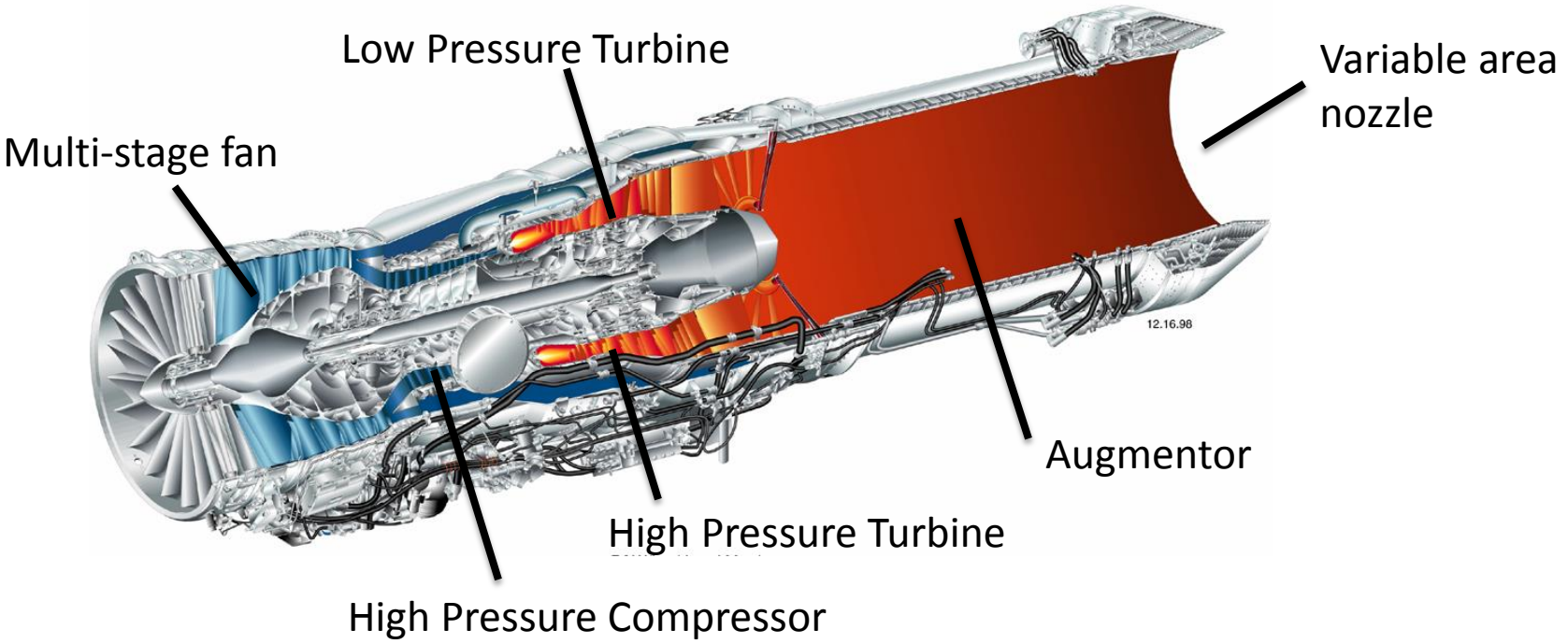
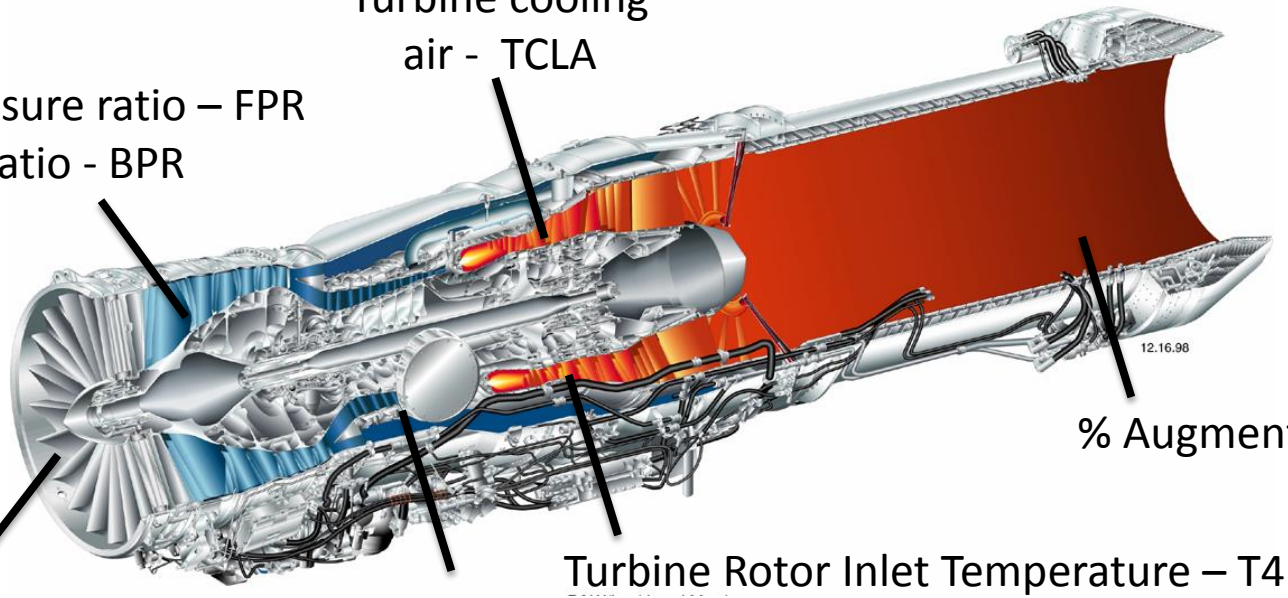


Image credit: Pratt & Whitney

Important Design Parameters



Turbine cooling air - TCLA

Fan pressure ratio – FPR

Bypass ratio - BPR

% Augmentation

Turbine Rotor Inlet Temperature – T41

Total fan flow

Overall Pressure Ratio - OPR

Image credit: Pratt & Whitney

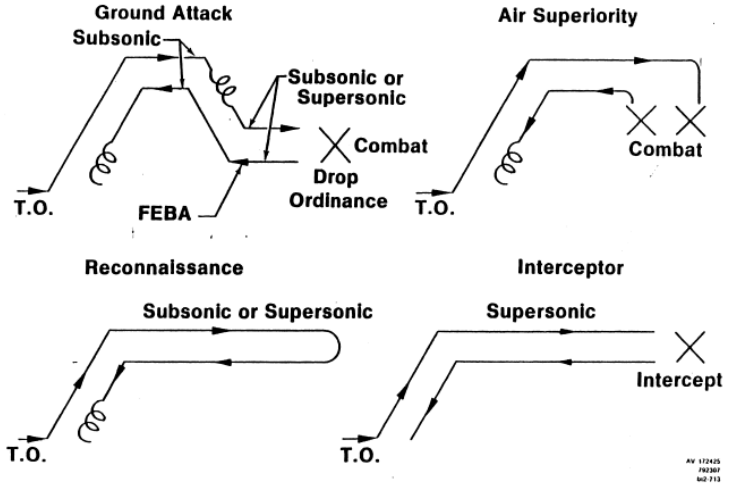
Designed For A Mission

Engine's purpose: achieve the mission

Aircraft cares about Specific Excess Power "Ps"……capability of aircraft to change its energy state - thrust

Radius/loiter capability brings the battle to enemy – fuel efficiency

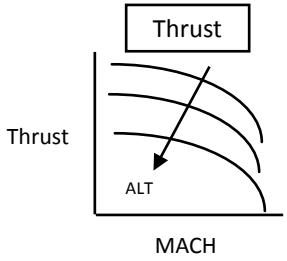
5th generation fighter engines add low observables demand: significant challenge

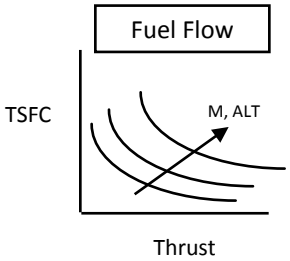


$$P_s = \frac{(\boldsymbol{Thrust} - Drag) * Velocity}{Weight}$$

Image credit: Pratt & Whitney

Designed For A Mission





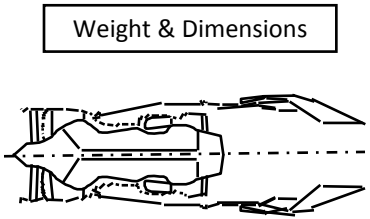
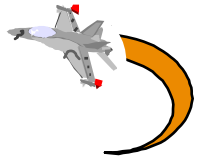


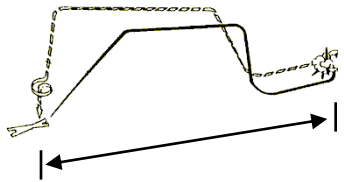
Image credits: Pratt & Whitney

Aircraft Performance

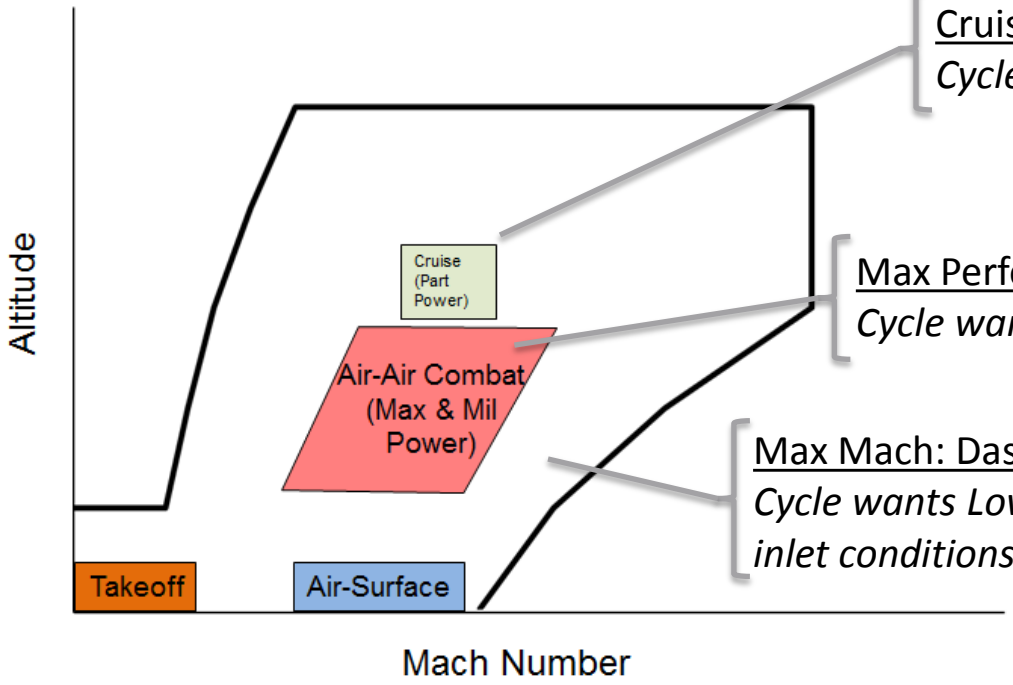


Accel time
Turn rate
Rate of climb

Aircraft Radius



Envelope vs Engine



Cruise: Fuel efficiency = radius/loiter time

Cycle wants High BPR, Low FPR, High OPR/T3

Max Performance: Ps, accel, turn, climb

Cycle wants Low BPR, High FPR, High OPR/T3

Max Mach: Dash

Cycle wants Low BPR, High FPR, OPR/T3 that allows inlet conditions

Image credit: Pratt & Whitney

Thrust To Weight

Enables high aircraft Ps

High thrust/pound of airflow (specific thrust)

Evolution in architecture, materials, and design systems enabled modern 5th gen engine

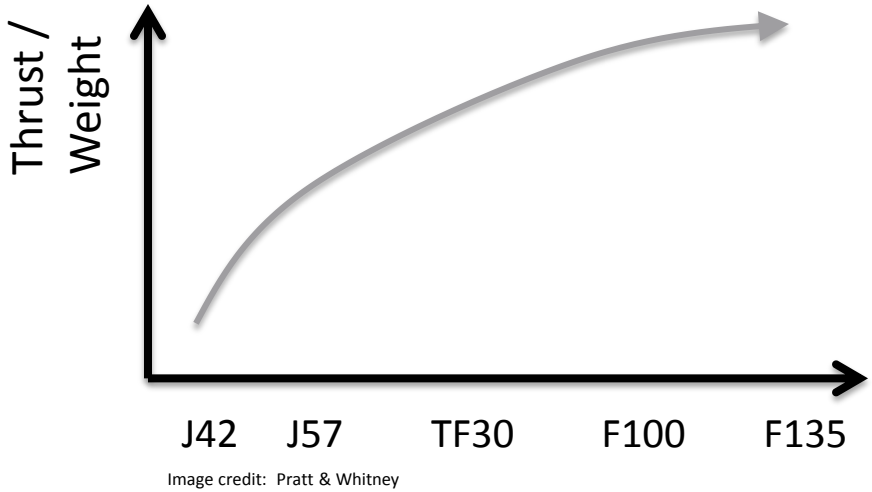


Image credit: Pratt & Whitney

J42 Single spool, Centrifugal comp.

J57/J52 Twin Spool, Axial comp.

TF30 Turbofan, Afterburner

F100 Fan high, Hot section materials, Modern design systems

F135 Reduced part core, FADEC, Advanced materials

Fuel Efficiency

High T41 enables optimized cycle

World class components

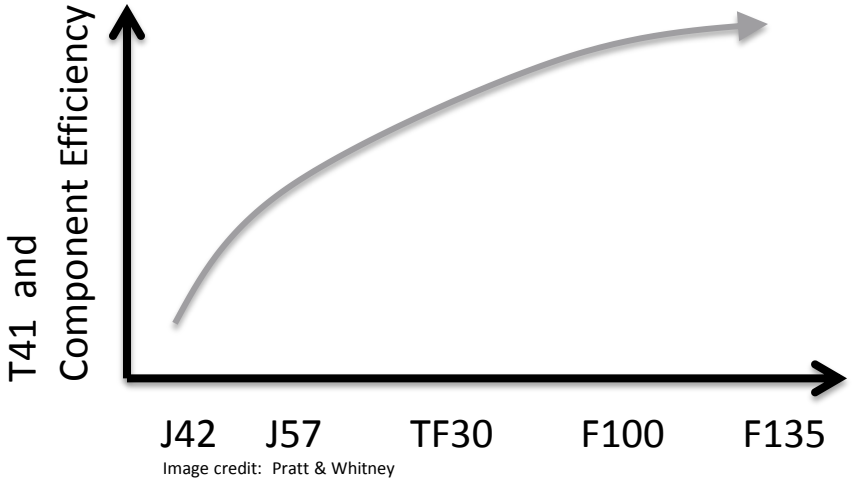


Image credit: Pratt & Whitney

J42 Single spool, Centrifugal comp.

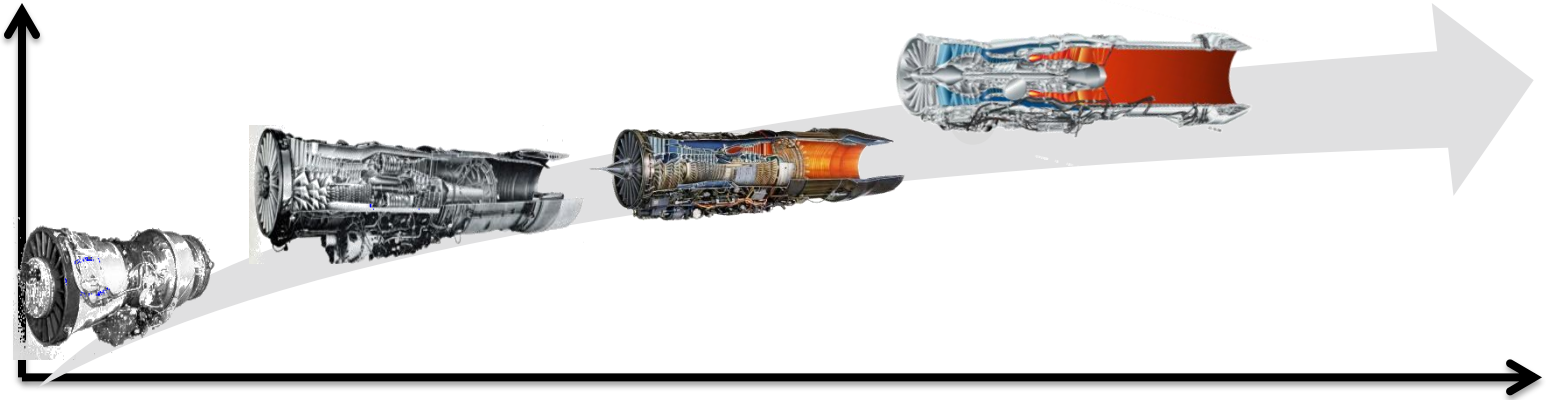
J57/J52 Twin Spool, Axial comp.

TF30 Turbofan, Afterburner

F100 Digital Electronic Control, Hot section materials, Modern design systems

F135 World class efficiency, Advanced hot section, Versatile engine cycle

Manufacturing and Tools Enablers



J57	TF30	F100	F135	Next
General machining Basic computing Empirical aero Bladed disks	Sheet metal Nickel alloys Mainframes Powder metallurgy	Chem milling CFD Single crystal Advanced alloys	Integrally bladed rotors Composites Advanced cooling Additive manuf Advanced cooling Distributed computing	Advanced materials Nextgen cooling Automated workflows Deeply integration design tools

Image credits: Pratt & Whitney

Reliability and Safety

10x reduction in Class A mishap rate since the 1950s as engine capability dramatically increased

Evolution in design systems, development, and control and sensing

Single engine safety by design for 5th gen fighter

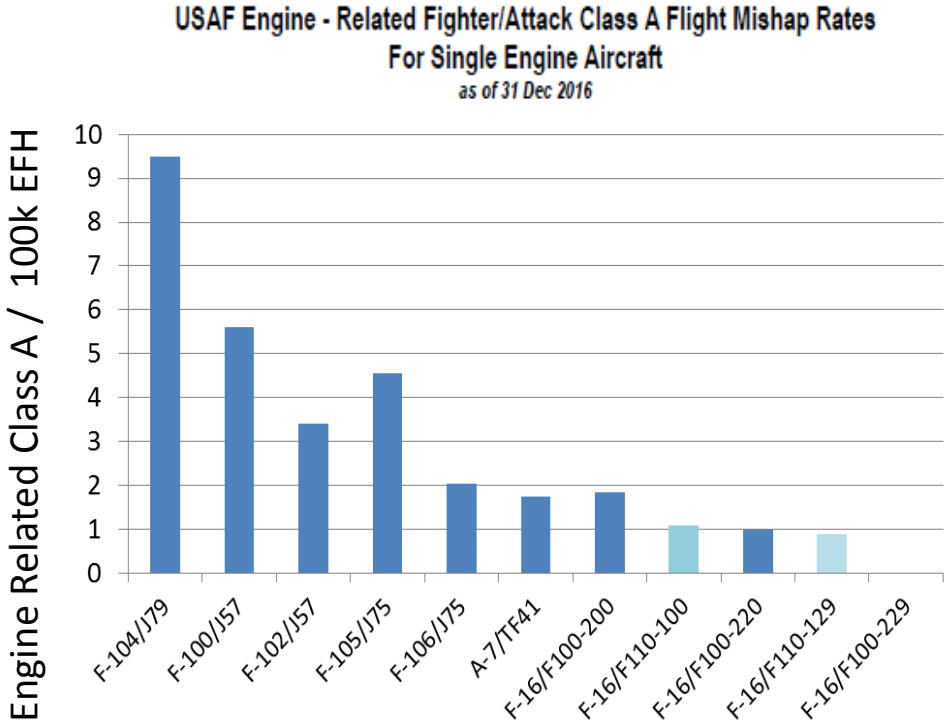


Image credit: USAF Safety Center

Cost of Ownership

Long life engine design

Fault Detection & Accommodation

Prognostics Health Management

Condition Based Maintenance and Usage Based Lifing

Reliable, Maintainable, Supportable

Fleet Metric	Usage Based Lifing (Life Limited Parts)	Advanced Trending and Prognostics	Usage Driven Inspection (Turbine Durability	Advanced Sensors / Damage Detection
Engine Total Cost of Ownership	REDUCED	REDUCED	REDUCED	REDUCED
In Flight Shutdown Rate	REDUCED	REDUCED		REDUCED
Maintenance Man-Hours Rate			REDUCED	REDUCED
Mean Time Between Removals	IMPROVED	IMPROVED		
Unscheduled Removals		REDUCED	PREDICTED	PREDICTED

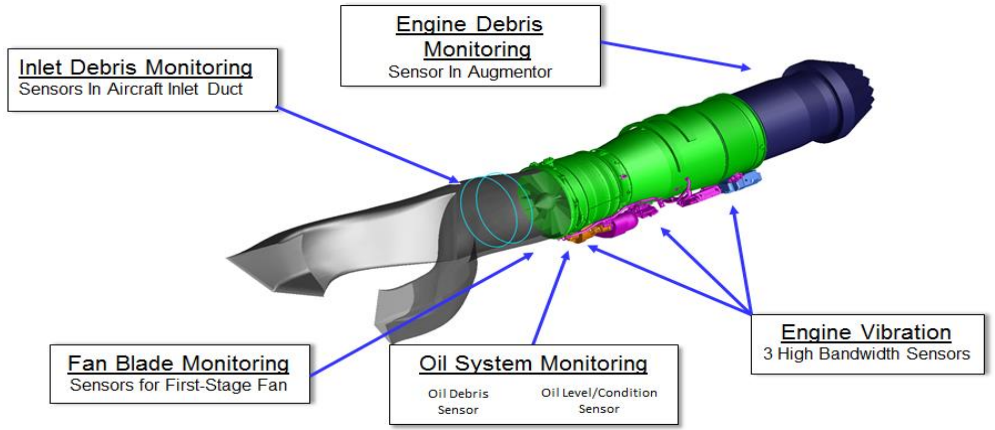


Image credit: Pratt & Whitney

What's To Come

Photo credit: Pratt & Whitney

Sustainment and fleet growth

Technology incorporation for:
- Increased thrust
- Increased radius
- Improved survivability

Key Technologies to enable:
- Higher efficiency core
- More effective turbine cooling
- Next generation materials

Thank you

Image credit: Pratt & Whitney