

Introduction to Design

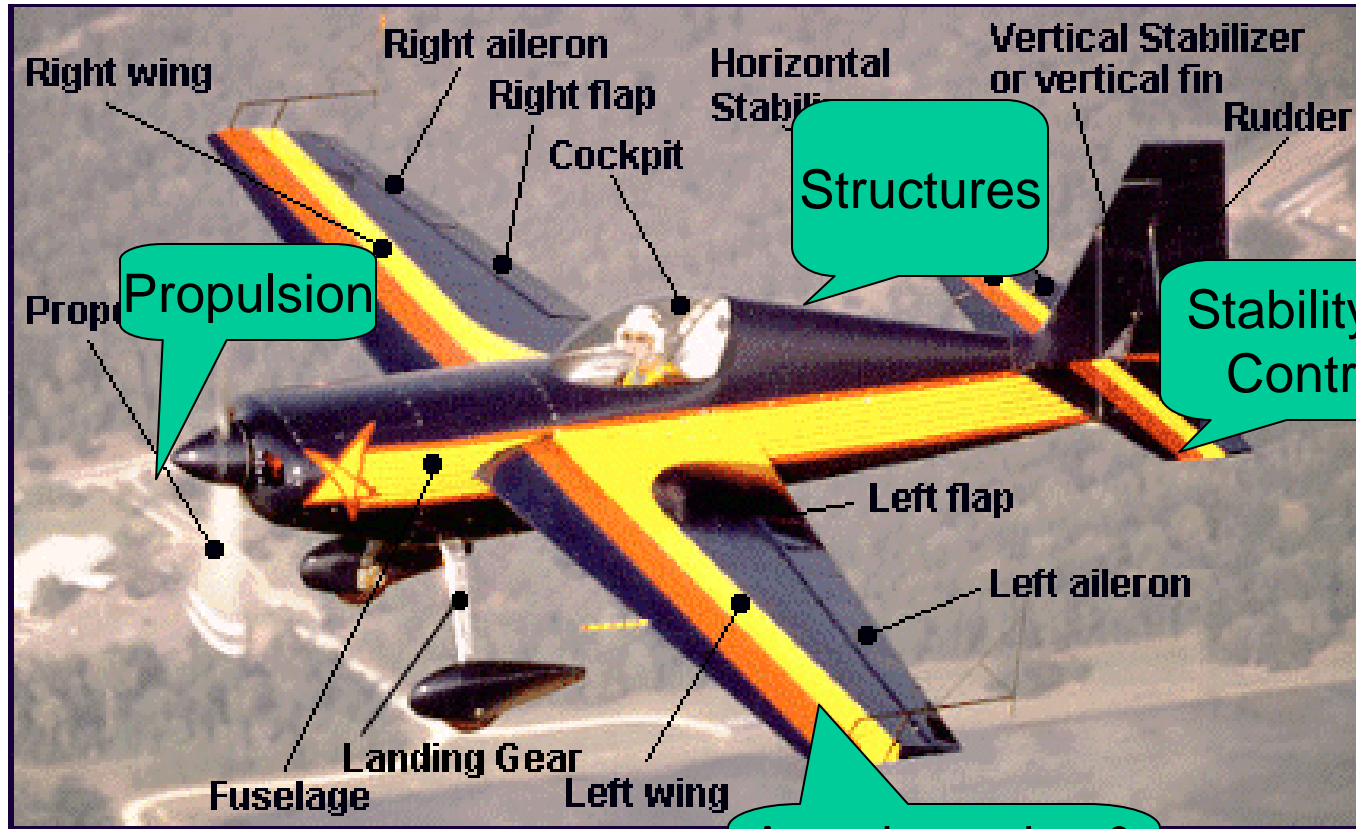
AE 1350



How Airplanes Fly

1. Lift generated to oppose Weight
 - Example: Wing with trailing edge
 - Weight kept to a minimum
2. Thrust generated to oppose Drag
3. Structure is strong/stiff enough
 - Stays together under maximum forces
 - Deflections low enough that aerodynamic forces still OK
4. Can be trimmed (moments brought to zero)
i.e. “balanced”
5. Either stable OR controllable

Disciplines



Design

Propulsion

Structures

Stability & Control

Aerodynamics & Performance

Specification And Standards

- The designer needs to satisfy
 - Customer who will buy and operate the vehicle
(e.g. Delta, Military, an individual)
 - Government Regulators
(U.S., Military, European, Japanese...)

Customer Specifications

- Performance:
 - Payload weight and volume
 - How far and how fast it is to be carried
 - How long and at what altitude
 - Passenger comfort
 - Flight instruments, ground and flight handling qualities
- Cost
 - Price of system and spares
 - Useful life
 - Maintenance hours per flight hour
- Firm order of units, options, delivery schedule, payment schedule



Typical Government Standards

- Civil
 - FAA Civil Aviation Regulations define such things as required strength, acoustics, reliability, take-off and landing performance, emergency egress time
- Military
 - May play a dual role as customer and regulator
 - MIL SPECS (Military specifications)
 - May set minimum standards for Mission turn-around time, strength, stability, speed-altitude-maneuver capability, detectability, vulnerability

Life Cycle

- The average airplane gets major upgrades five times in its lifetime
 - New avionics, interiors, etc.
- Airplane lifetimes are exceeding 50 years in some cases



KC-135

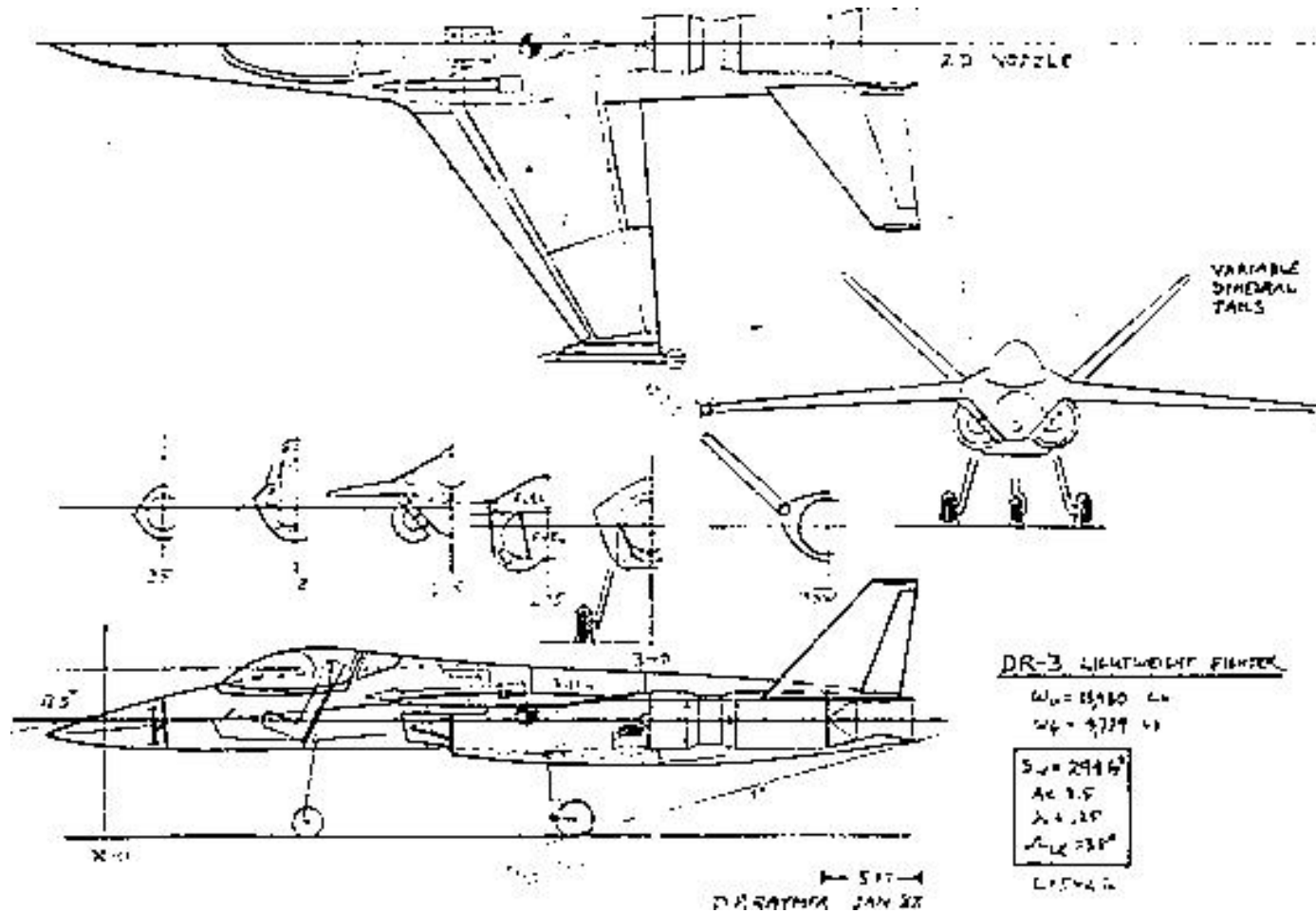
Design Is, In General,

- A team effort
- A large system integration activity
- Iterative
- Creative, knowledge based
- Typically happens in three stages
 - Conceptual design
 - Preliminary design
 - Detailed design and Integration

Conceptual Design

- What will it do?
- How will it do it?
- What is the general arrangement of parts?
- The end result of conceptual design is an artist's or engineer's conception of the vehicle/product
- May carry multiple – very different – versions to later stages

Conceptual Designs



Dan Raymer sketch

Conceptual Designs



1988 Lockheed Design

Preliminary Design

- How big will it be?
- How much will it weigh?
- What engines will it use?
- How much fuel or propellant will it use?
- How much will it cost?
- Many of the techniques/methods from this course apply here
- Classic example of multi-attribute decision making
 - Many decisions to make
 - Many outcomes to predict and prioritize

Preliminary Design Analysis

Wing sizing spreadsheet

Written by Neal Willford 12/29/03 for Sport Aviation

Based on methods presented in "Technical Aerodynamics" by K.D. Wood, "Engineering Aerodynamics" by W.S. Diehl, and "Airplane Performance, Stability and Control" by Perkins

This spreadsheet is for educational purposes only and may contain errors. Any attempt to use the results for actual design purposes are done at the user's own risk.

Input required in yellow cells

Wing area sizing

| | | | |
|----------------------|----------------------|-------------------|--------------------------------|
| A/C weight: | 1150 lbs | Flaps up Clmax: | 1.42 get from Airplane CL page |
| Desired stall speed: | 45 knots, flaps up | Flaps down Clmax: | 1.78 get from Airplane CL page |
| Desired stall speed: | 39 knots, flaps down | | |

Minimum wing area needed to meet the flaps up and flaps down stall speed requirements. Use the larger of the two areas

| | |
|------------------|---|
| Min. Wing Area = | 125.3 sq ft, to meet desired flaps down stall speed |
| Min. Wing Area = | 118.0 sq ft, to meet desired flaps up stall speed |

Wing span sizing. Choose span to obtain desired rate of climb and ceiling

| | | | |
|-------------------------------------|--|--------------------------|--|
| Flat plate area: | 4.00 sq ft | | |
| Total wing area: | 122.4 sq ft | | |
| Wingspan: | 35.5 ft (upper wingspan for a biplane or wingspan for a mor estimated k1 = | 1.00 biplane span factor | |
| Lower wingspan: | 0 ft (lower wingspan for a biplane. Enter 0 for a monoplane) | | |
| Wing gap: | 0 ft (distance between upper and lower wing if the a/c is a biplane. Enter 0 for a monoplane) | | |
| max fus width: | 3.5 feet | est airplane 'e' = | 0.72 Oswald factor |
| Max horsepower: | 79 bhp | Max prop RPM: | 2422.907489 |
| Prop W. R.: | 0.066 chord/Diameter @ 75% prop radius | | |
| Peak Efficiency 2 Blade Prop Dia. = | 66 inches | Peak Efficiency Pitch = | 63 inches |
| Propeller Diameter: | 63 inches | mu = | 0.03 .03 concrete, .05 short grass, 0.1 long grass |
| Est Prop efficiency = | 0.75 | Vto/Vstall | 1.15 ratio of takeoff speed to stall speed (1.15 to 1.2) |
| Prop efficiency: | 0.75 ** iterate until equals estimated prop efficiency (then subtract .03 if using a wooden propeller) | | |

Estimated sea level standard day performance

| | | | |
|-----------------|---------------------|------------|---|
| Vmax = | 127 mph = | 110 knots | Fixed Pitch Propeller Performance |
| V best ROC = | 72 mph = | 63 knots | max ROC = |
| Vmax L/D = | 65 mph = | 56 knots | Abs. Ceiling = |
| V min pwr = | 49 mph = | 43 knots | Service Ceiling = |
| Vstall, clean = | 50.9 mph = | 44.2 knots | Constant Speed Propeller Performance |
| Vstall, flaps = | 45.4 mph = | 39.4 knots | max ROC = |
| Wing loading = | 9.4 lbs/sq ft | | Abs. Ceiling = |
| Power loading = | 14.6 lbs/horsepower | | Service Ceiling = |

Estimated takeoff and landing performance

| | | | |
|--------------------------------|-------------------------------------|----------------------------|----------|
| Fixed Pitch Prop | | Constant Speed Prop | |
| T.O. distance = | 609 feet | T.O. distance = | 414 feet |
| T.O. over 50' = | 929 feet | T.O. over 50' = | 686 feet |
| Landing distance ground roll = | 420 feet, flaps down (1.15xVstall) | | |
| Landing over 50' obstacle = | 1023 feet, flaps down (1.15xVstall) | | |

Estimated power off sink rate (based on method in the March 1990 issue of Sport Aviation)

| | |
|------------------|--|
| windmilling e: | 0.48 APPROXIMATELY 2/3 of power on 'e' |
| min sink speed = | 47 knots = 54 mph |
| sink rate = | 506 ft/min |

Background calc

Cdo =

Lp =

Lt =

Ls =

lambda =

Wing AR =

lamda cnsspd =

Cs 3bl =

L/Dmax =

Prop/body int =

Propeller advanc

T (fixed pitch) =

Tc (fixed pitch) =

T (constant spee

Tc (constant spe

R =

Dc =

Xt fixed pitch =

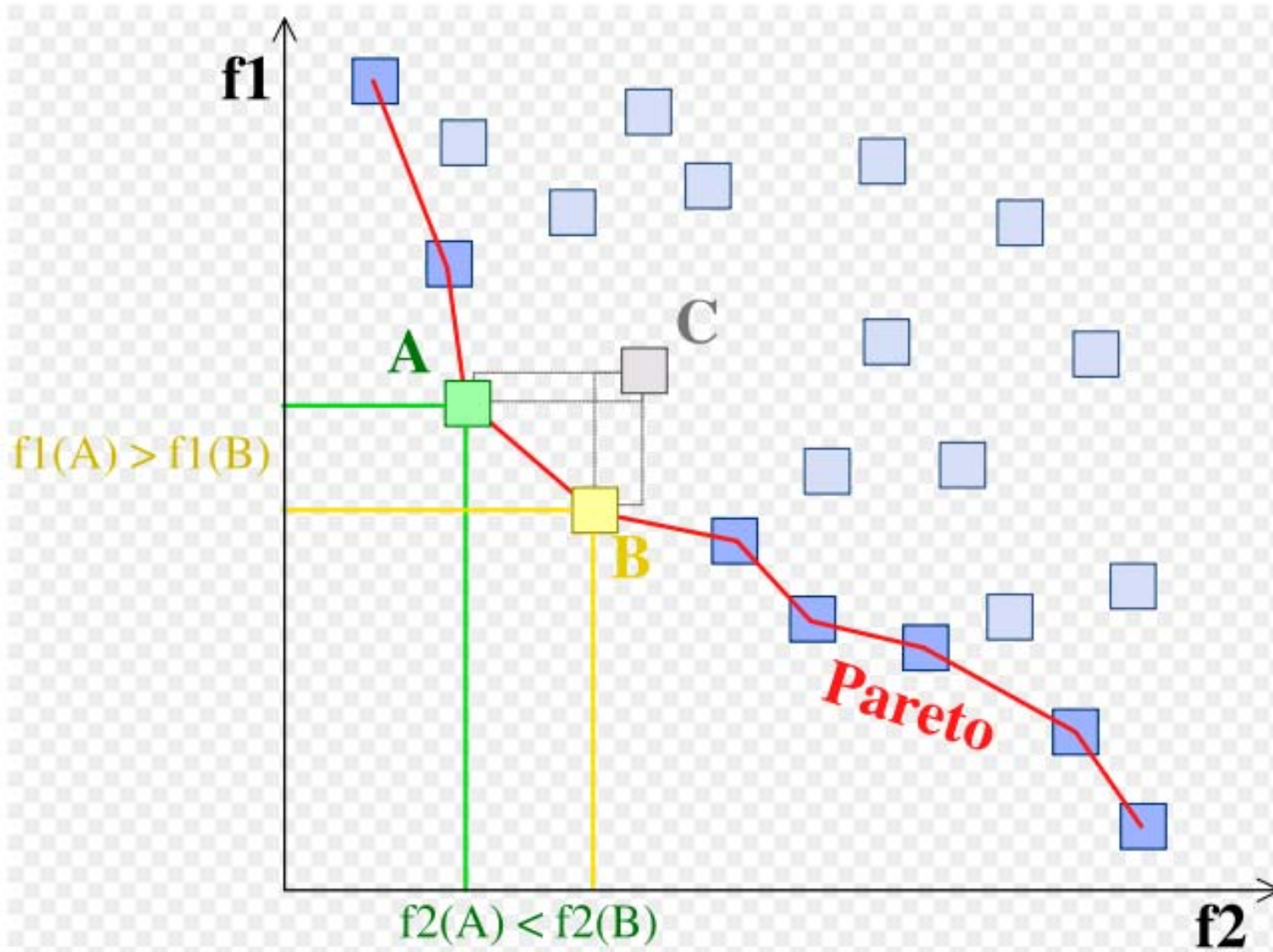
Ht fixed pitch =

Xt constant spee

Ht constant spee

T.O. Speed =

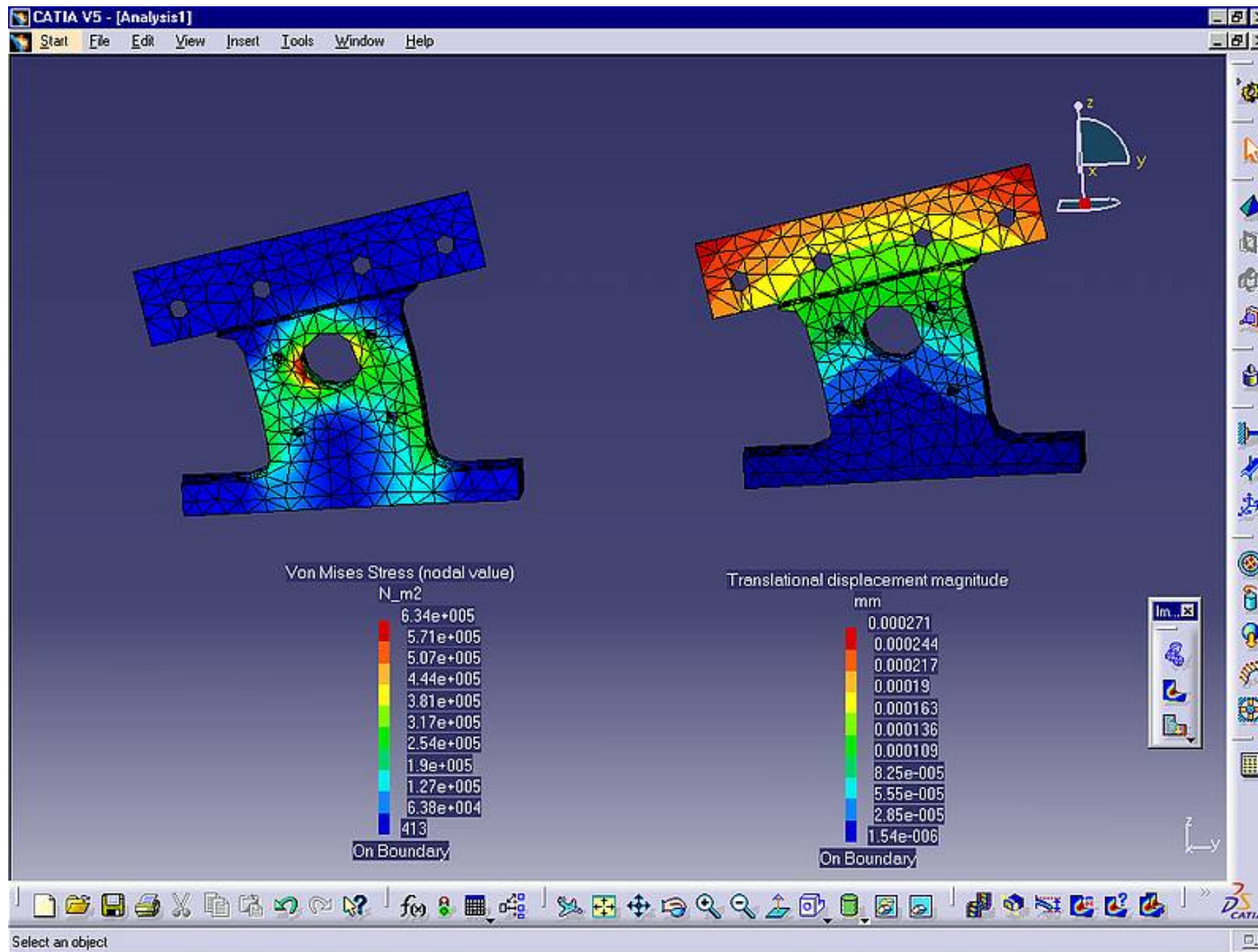
Pareto Frontier



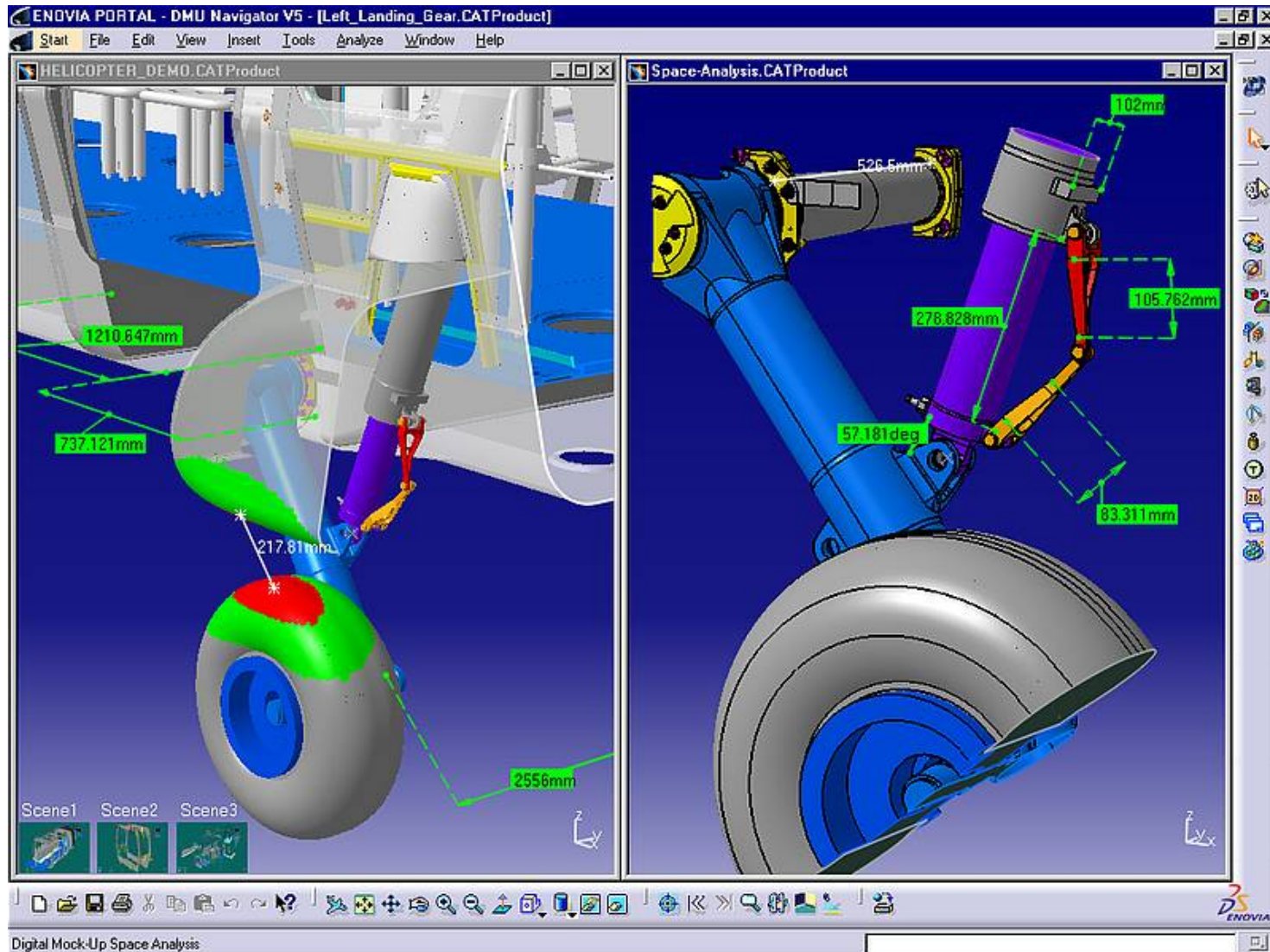
Detailed Design

- How many parts will it have?
- What shape will they be?
- What materials?
- How will it be made?
- How will the parts be joined?
- How will technology advancements (e.g. lightweight material, advanced airfoils, improved engines, etc.) impact the design?
- How will it be maintained?
- How will it be upgraded?

Detailed Design

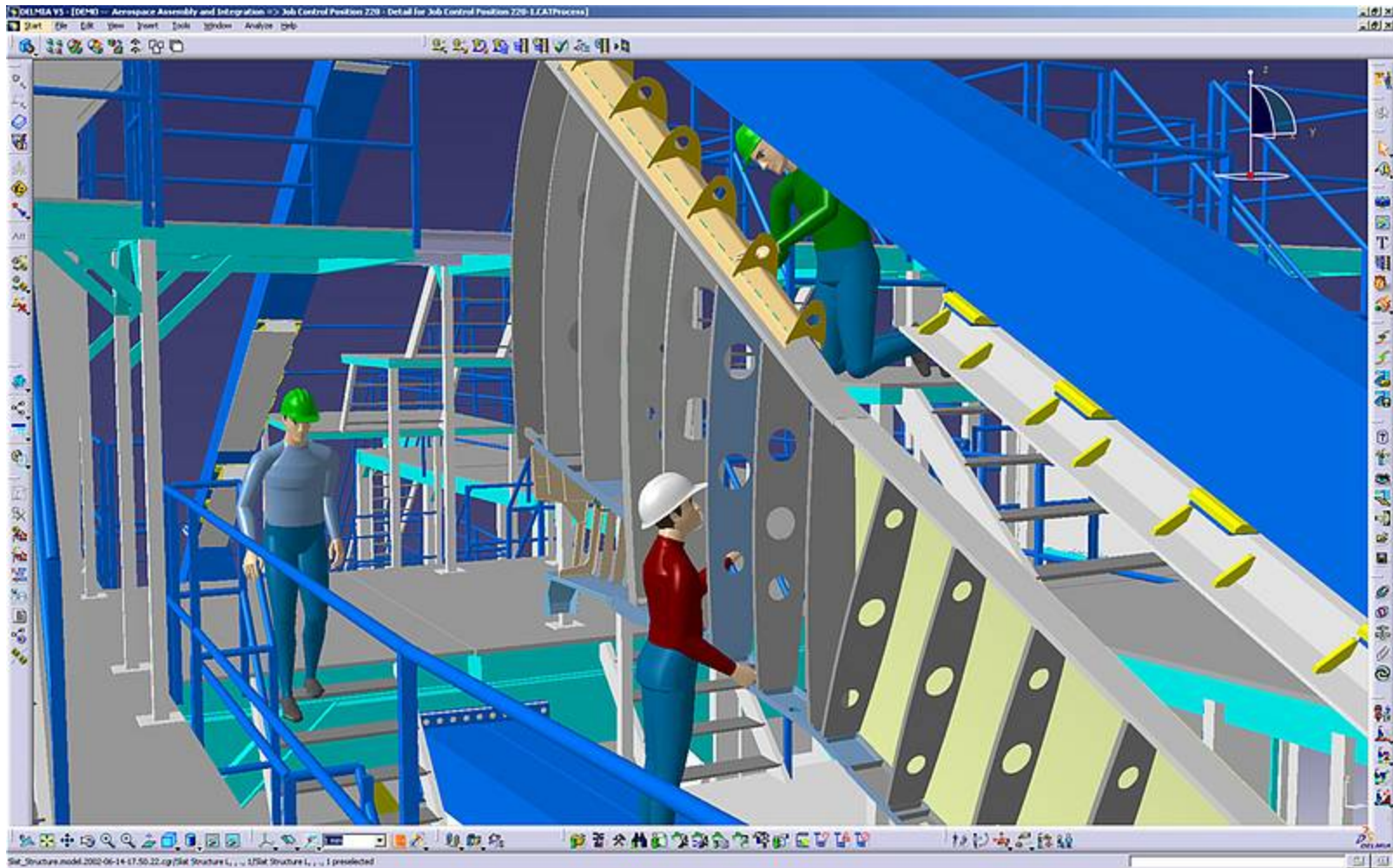


Detailed Design



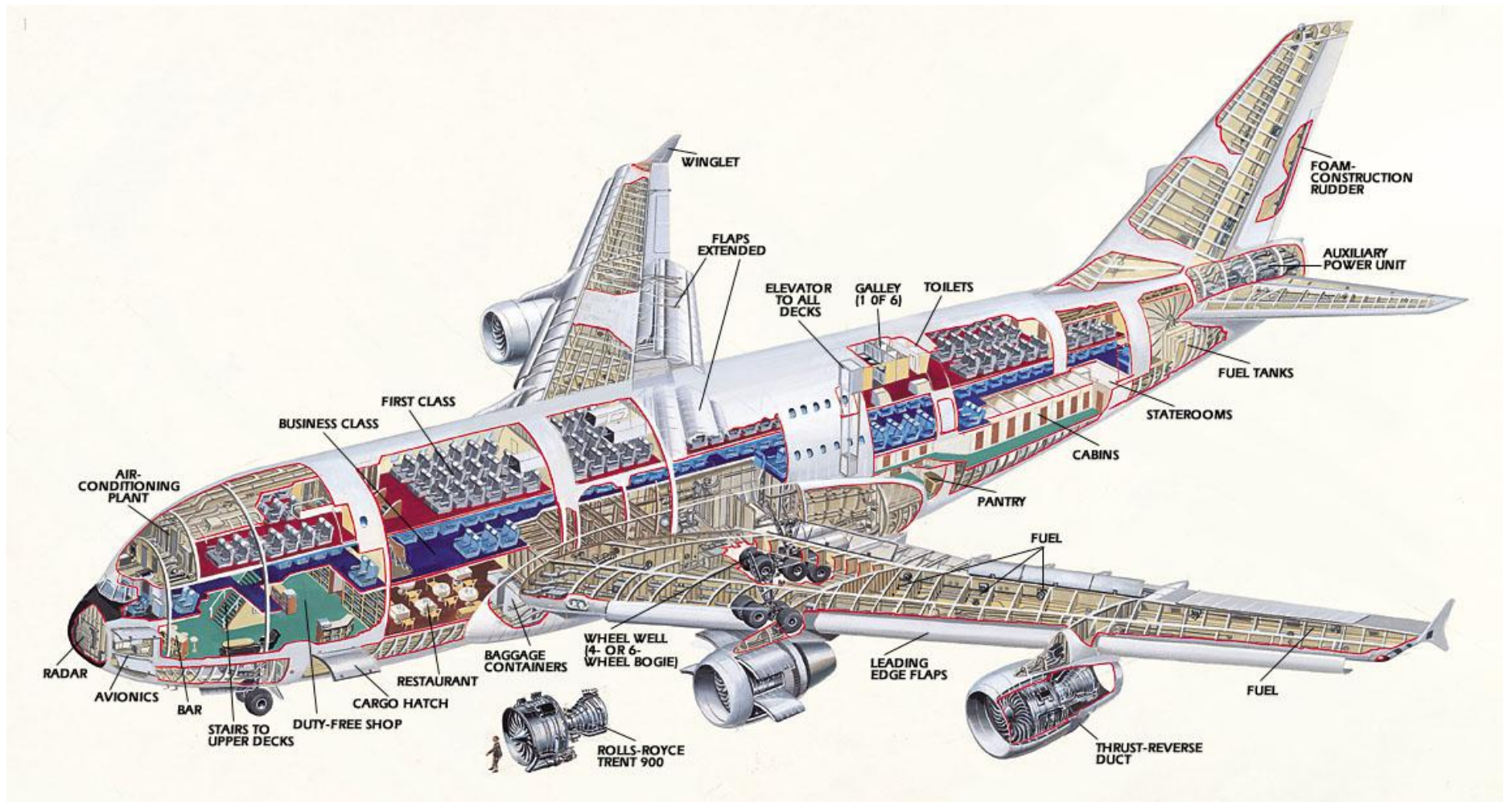
Dassault Systems - CATIA

Detailed Design



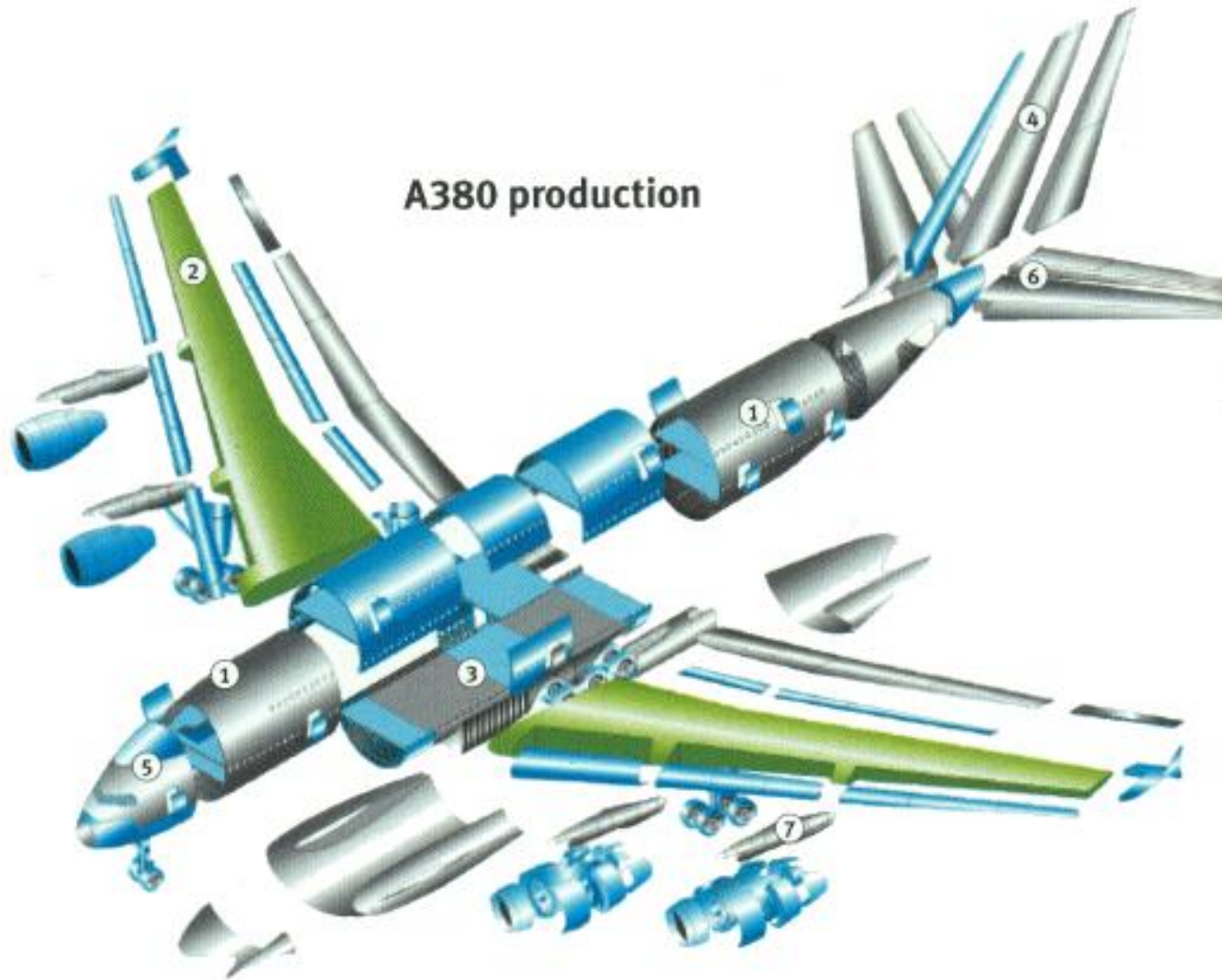
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A380 Arrangement



Cutaway Diagram

A380 Production



- ① Hambourg (All.)
- ② Broughton (UK)
- ③ St. Nazaire/Nantes (France)

- ④ Stade (All.)
- ⑤ St. Nazaire/Méaulte (France)
- ⑥ Getafe/Puerto Real (Esp.)
- ⑦ Toulouse (France)

- AIC manufacturing units
- Risk-Sharing Partners
- Risk-Sharing Partners sub-assemblies

Aerospace Detail Design/Integration

- Lot of analyses to support design decisions
- Ground testing and simulation, examples:
 - Wind tunnel tests
 - Flight simulation
 - Full scale mock-up
 - Fatigue tests
 - Ultimate load tests
- Flight tests

System Integration

- Aircraft/Spacecraft Design often involves integrating parts, large and small, made by other vendors, into an airframe or spaceframe
- Parts include
 - Engines, landing gear, shock absorbers, wheels, brakes, tires
 - Avionics (radios, antennae, flight control computers, software)
 - Cockpit instruments, actuators that move control surfaces, retract landing gears, etc...

Examples of integration

- Providing smooth airflow into engine inlets free of debris
- Insuring that the hot engine does not damage the airframe structure
- Providing antenna locations with minimum electromagnetic interference
- Providing mountings for power actuators that deflect control surfaces, retract landing gear, etc.



A380 Fatigue Test



F-22 Flight Test

Air-data Probe



Spin Chute