High Altitude Long Endurance Unmanned Aerial Vehicles

HALE-UAVs

A Brief Introduction

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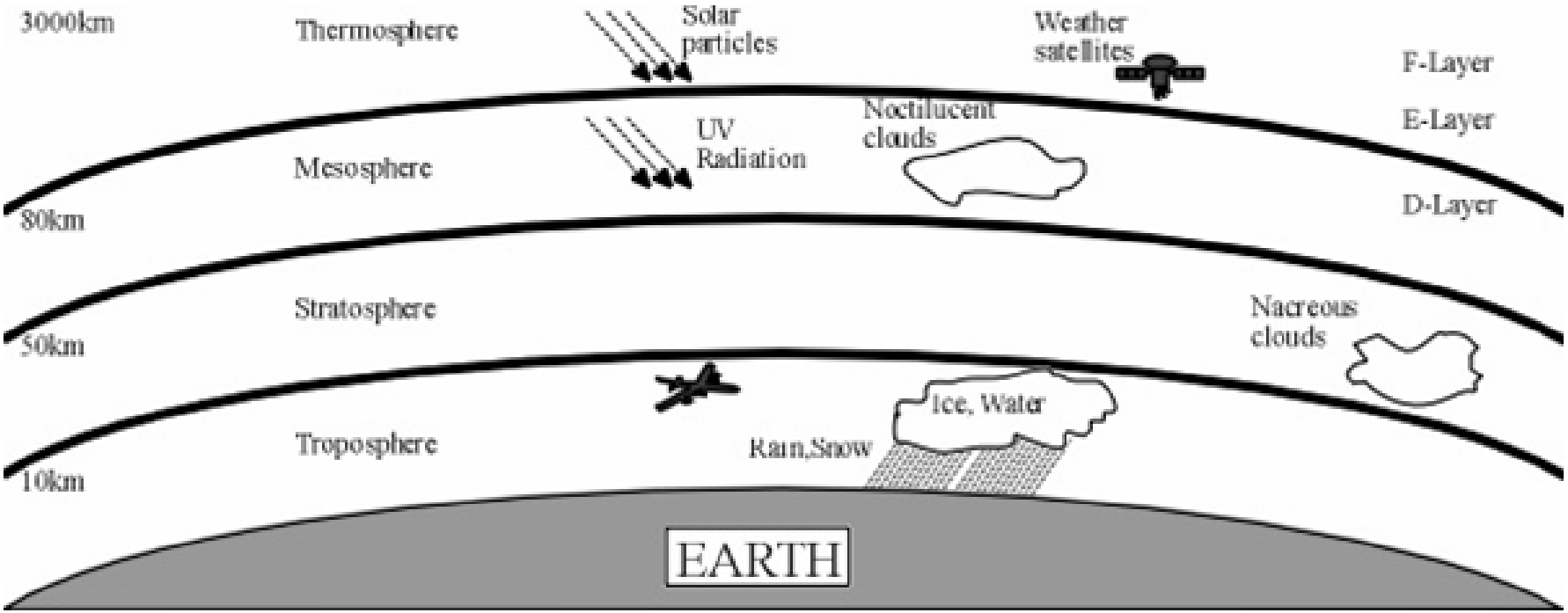
2012-15

High Altitude

How high is high?

High Altitude

How high is high?



High Altitude

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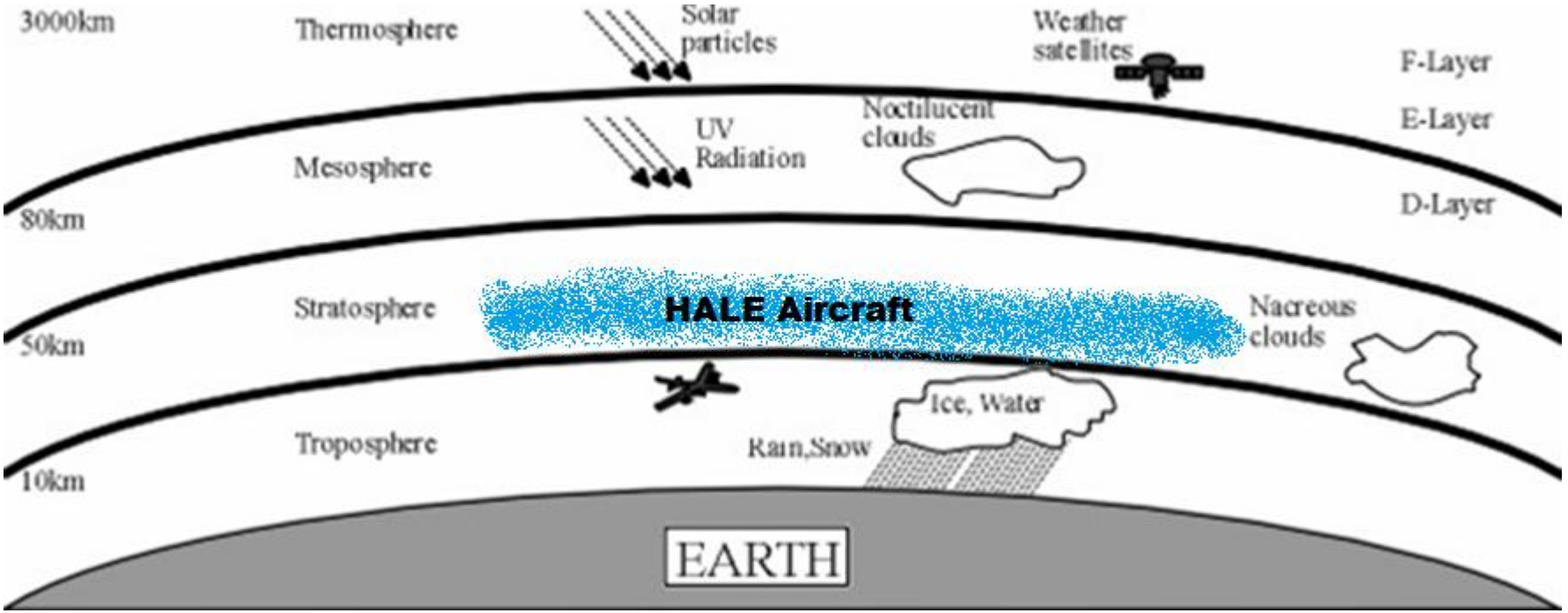
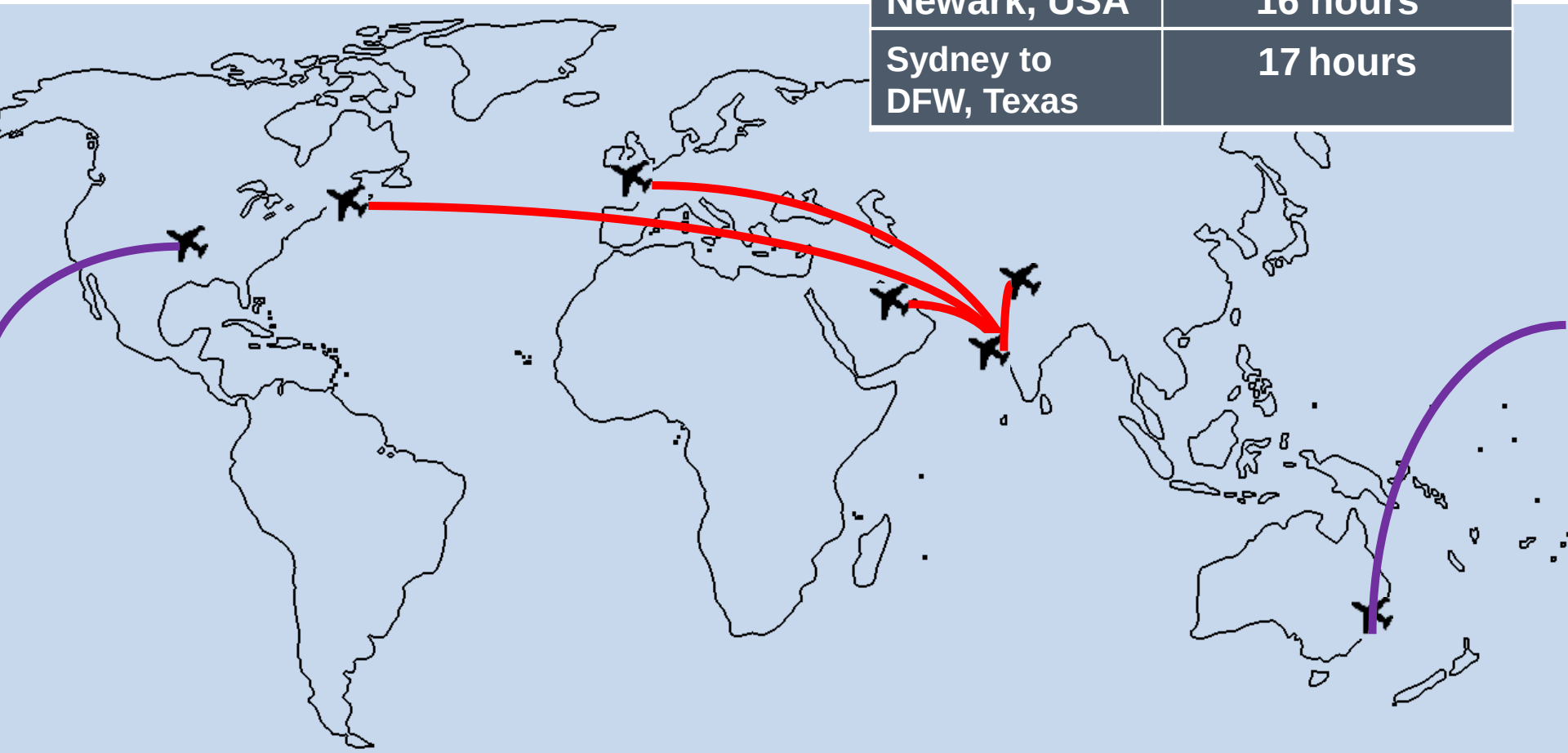


Long Endurance

How long is long?

- Flight durations from Mumbai

Mumbai To	Travel Time (at 10 km altitude, ~ 0.8 M)
Delhi	2 hours
Dubai, UAE	3 hours
Paris, France	9 hours
Newark, USA	16 hours
Sydney to DFW, Texas	17 hours



Long Endurance - Around the world

- Virgin Atlantic Global Flyer designed by Burt Rutan
- Around the world = Absolute World Record for the fastest nonstop unrefueled circumnavigation: 67 hours 1 minute.

Applications

Earth Science

Pseudo Satellites

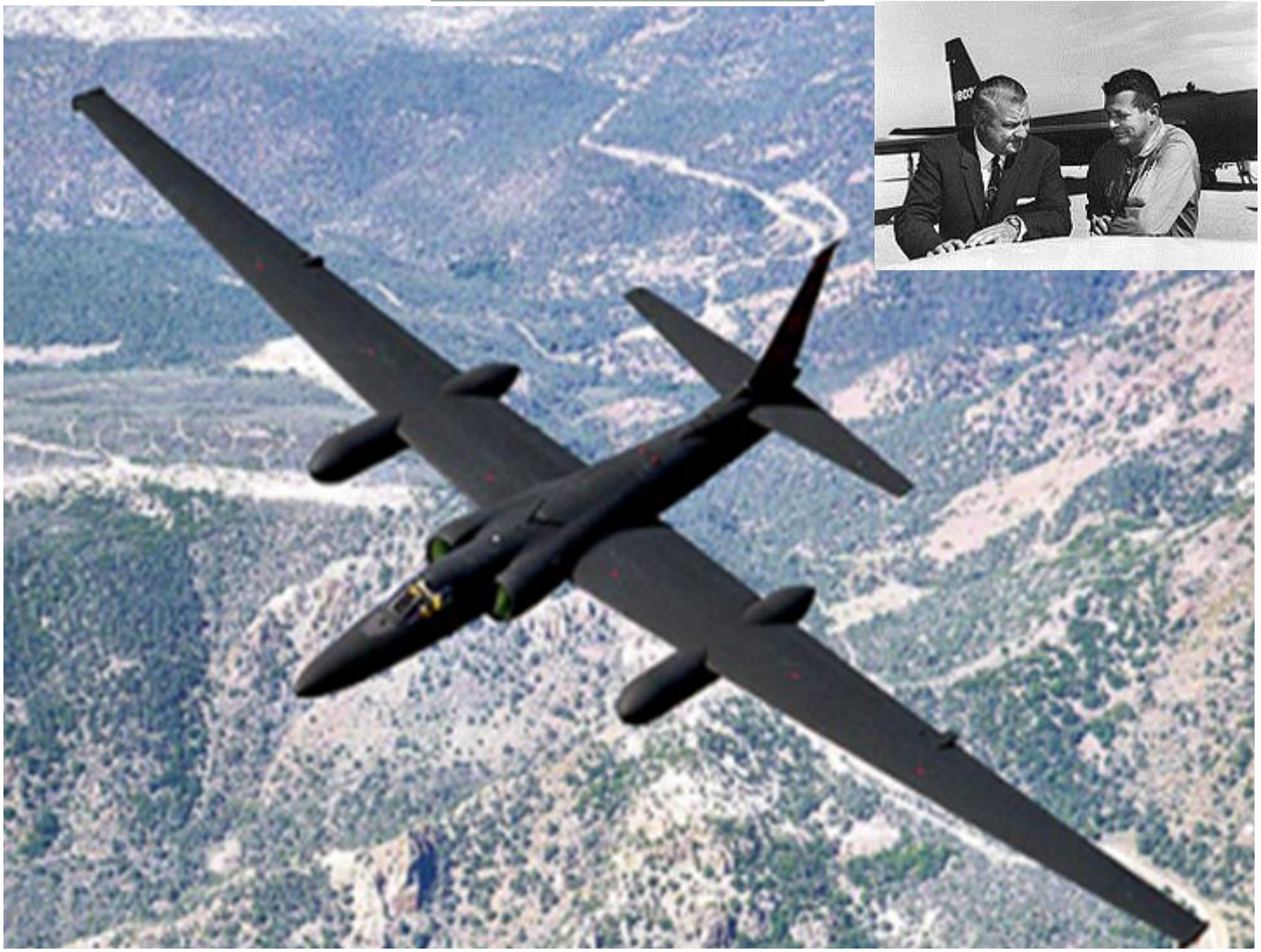
Surveillance

Key Mission Features

- Flies above
  - Weather
  - Interception
  - Commercial flights
- Payloads cover larger area of the earth at a time
  - SAR RADAR
  - Satellite Communication

Legacy HALE Aircraft

Lockheed U-2



Existing HALE Aircraft Designs

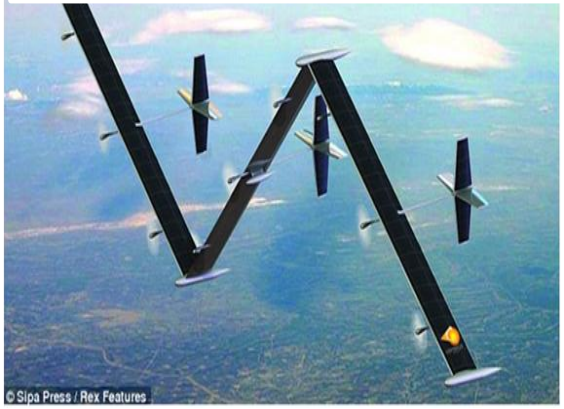
Northrop Grumman's Global Hawk RQ-4

AeroVironment Global Observer

Boeing Phantom Eye

Qinetiq Zephyr

Odysseus



NASA Helios

GLOBAL HAWK CASE STUDY

RQ 4A (2000)

RQ 4B (2007)

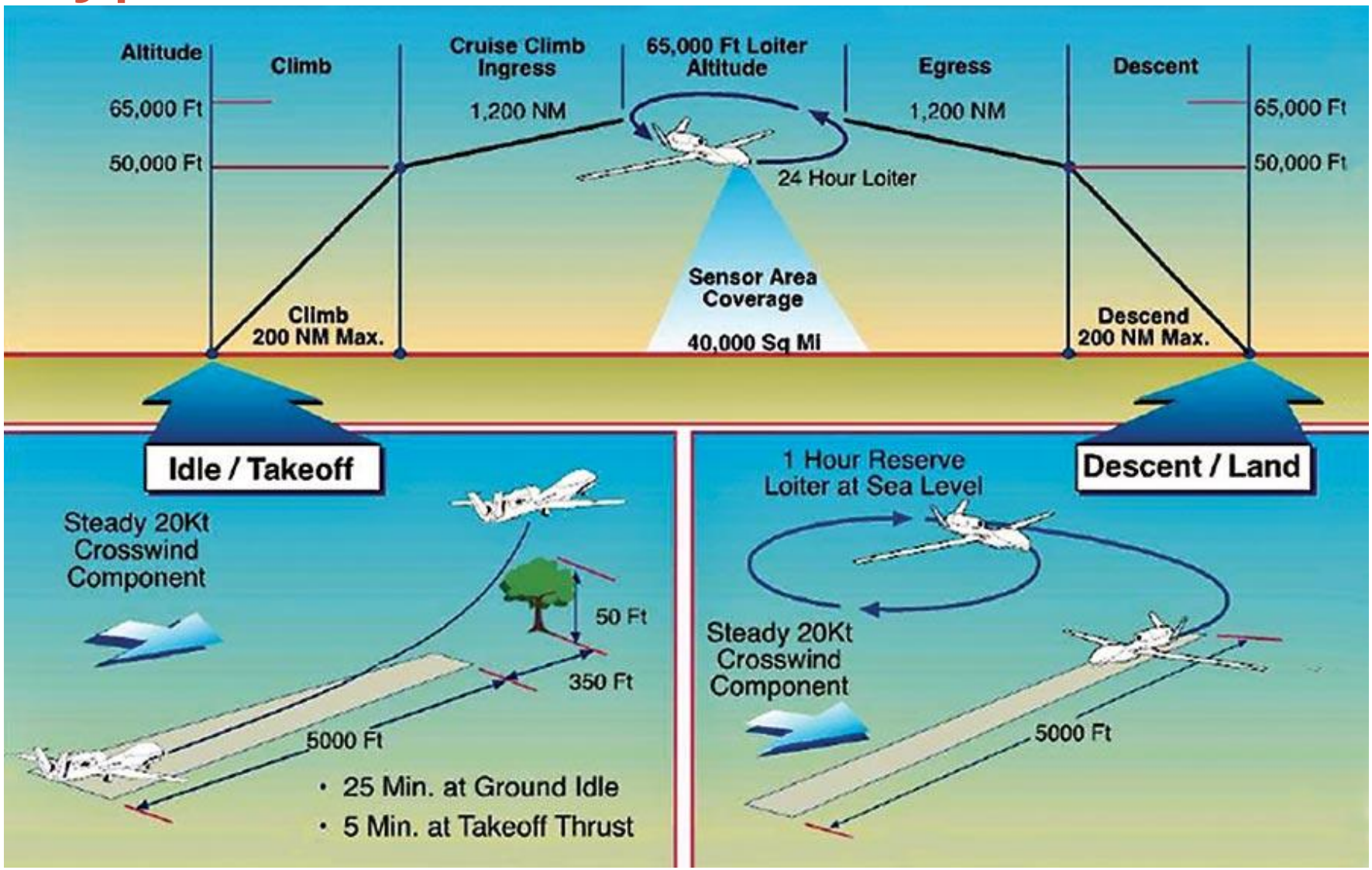
EuroHawk (2007)

RQ-4B Aircraft Specifications

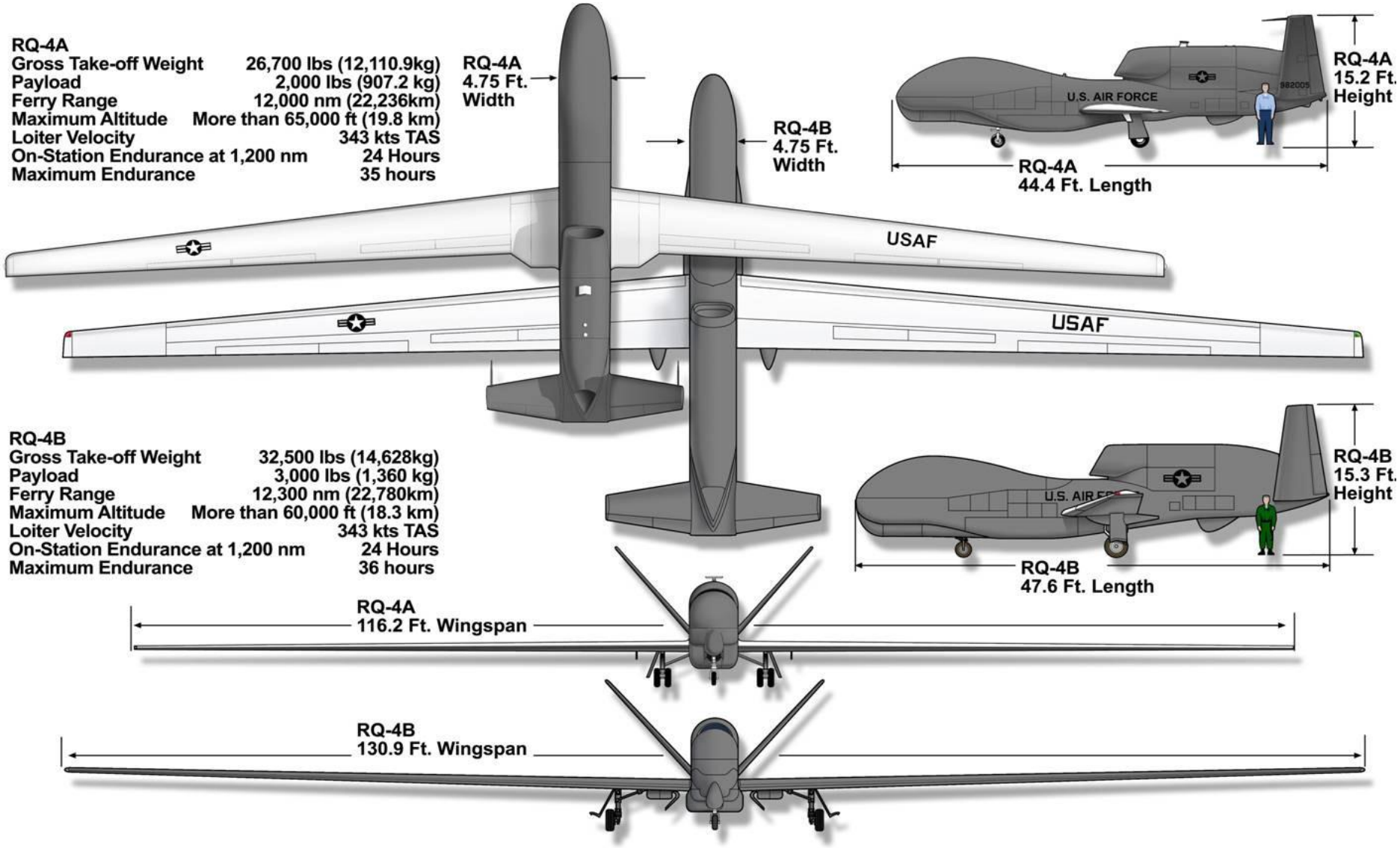
Endurance	32+ hours
(Ferry) Range	12,300 nm (~22,780 km)
Service Ceiling	60,000 feet (18.3 km)
Cruise Speed	310 knots (574 kmph) ~0.6 Mach
Flight Crew	3 remote pilots
Wingspan	39.9 m
Length	14.5 m
Engine	Turbo-fan, Rolls Royce F137-RR-100
Payload	Suite of RADAR and SIGINT
GTOW	14628 kg
Payload Weight	1360 kg (~9%)
Fuel Weight	6500 kg (~45%)
Empty Weight	6740 kg (~46%)

Source: RQ-4 Block 40 Global Hawk
http://www.northropgrumman.com/Capabilities/GlobalHawk/Documents/Datasheet_GH_Block_40.pdf

Typical Global Hawk Mission



Features of Configuration?



Crew

Monoplane/Biplane

High/mid/low wing

Engine type

Number of engines

Tail type

Landing Gear Configuration

??

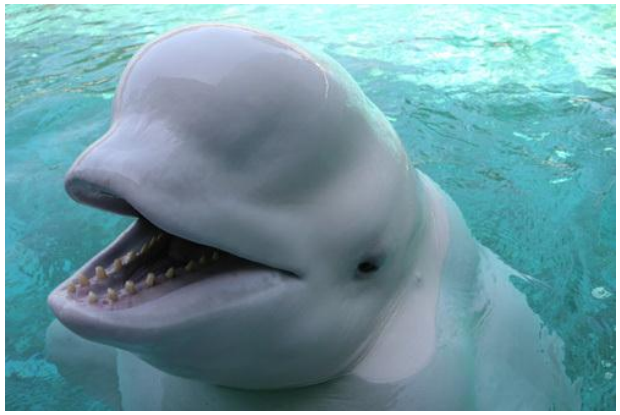
Design Features

- High Aspect Ratio Unswept wings

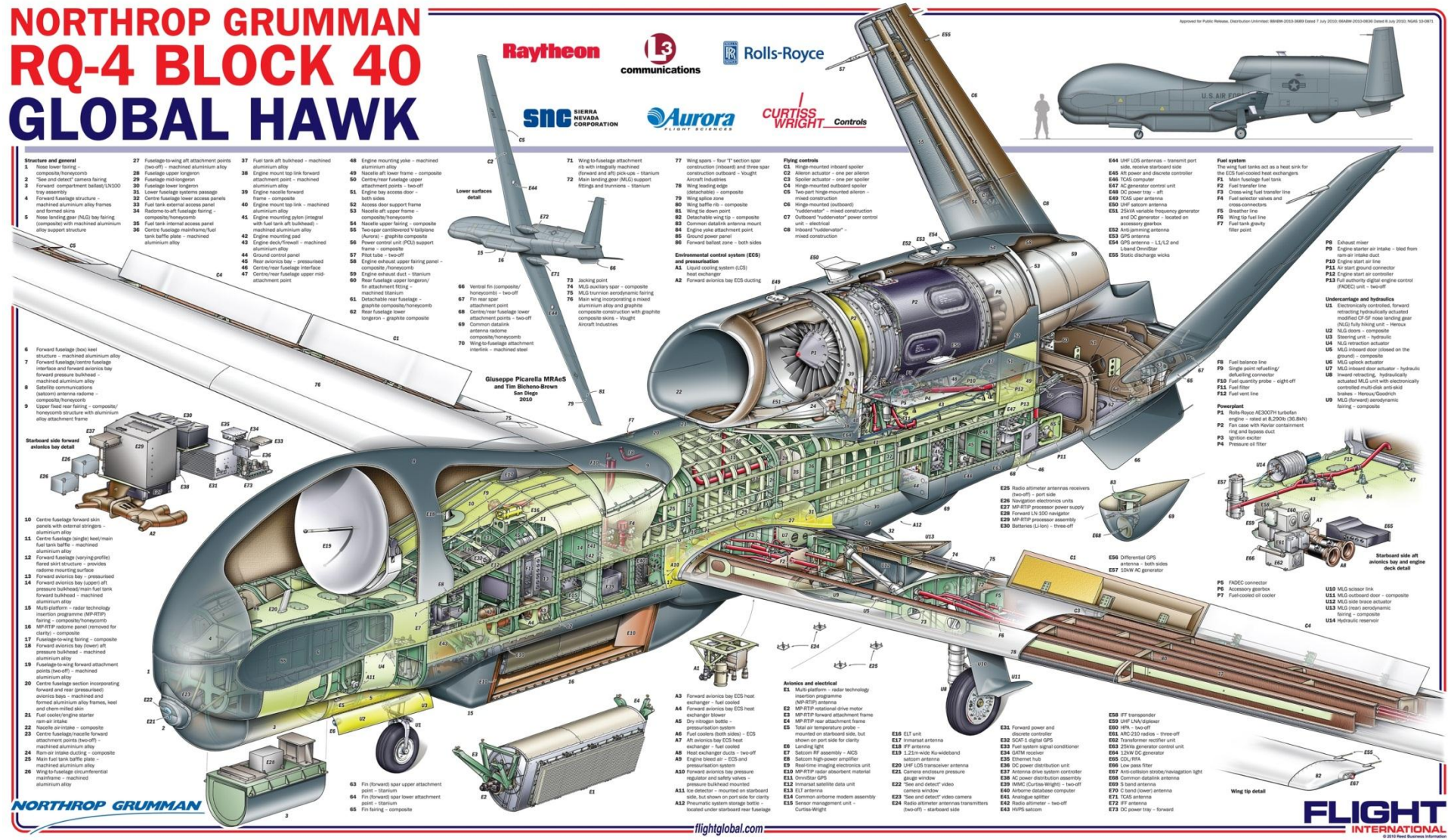
$$C_D = C_{D0} + \frac{{C_l}^2}{\pi\, e\, AR}$$

Design Features

- Bulging Beluga-whale nose



Inside the Global Hawk



Inside the Global Hawk Operations Centre

Sizing Method for a HALE UAV*

Step 1: Estimation of MTOW

- Empty Weight Fraction table*

UAV	Empty Weight Fraction
Predator – C	0.390
U-2S	0.445
Grob Stratos 2C	0.500
Global Hawk	0.460

- Crew weight = 0 (unmanned)

*Lloyd R. Jenkinson and James F. Marchman III, Aircraft Design Projects for Engineering Students, ISBN: 978-0-7506-5772-3, Elsevier Ltd., 2003

Sizing Method

- Mission Segment Weight Fractions:
  - As usual (Refer Global Hawk mission profile)
- Cruise segment weight fraction from Breguet Endurance equation:
  - SFC(cruise) for a medium bypass ratio turbofan engine = 0.55 lb/lb-hr*
    - For a 2020 engine, take cruise SFC = 0.47 – 0.50**
  - Reserve fuel = 10%
  - $L/D_{cruise} = L/D_{max}$ (Condition for Jet Aircraft Endurance)

* Lloyd R. Jenkinson and James F. Marchman III, Aircraft Design Projects for Engineering Students, ISBN: 978-0-7506-5772-3, Elsevier Ltd., 2003

** suggested by Dr. Scott Eberhardt, in Prof. Pant's lecture notes

Suggested values for max L/D

	L/D_{max} Range	Average L/D_{max}
Propeller Personal/Utility	9.6–14.2	12.1
Propeller Commercial Transport	13.8–18.5	16.3
Business Jet	13.0–15.6	14.3
Commercial Jet Transport	15.0–18.2	14.4
Military Transport/Bomber	17.5–20.5	18.9
Military Fighter (subsonic cruise)	9.2–13.9	11.0

Global Hawk* **33 to 34**

* from *Flight International, UAVs, page 28,5 /1/01. Source: Chaput*

Sizing Method

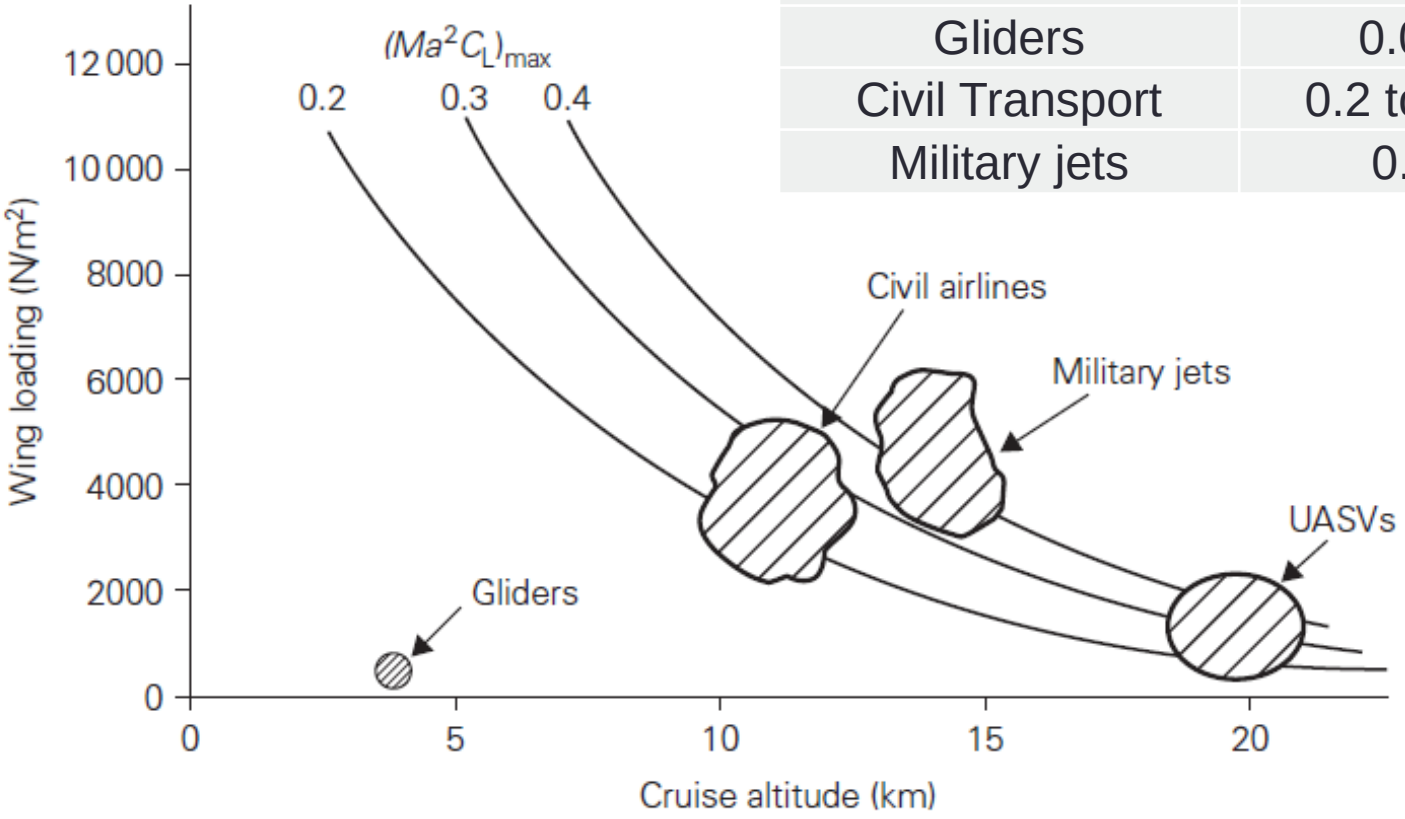
- GTOW Estimation:

$$W_0 = \frac{W_{crew} + W_{payload}}{1 - (WF_e + WF_f)}$$

Sizing Method

- Wing-loading Calculation, knowing $M^2 C_{Lmax}$ gives wing area

Class	$M^2 C_l$
Gliders	0.05
Civil Transport	0.2 to 0.4
Military jets	0.6



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Wing Planform Design

- High Aspect Ratio

Aircraft	L/D
Transport	7 - 9
Gliders	20 – 30

- Wetted area from Wing loading
- Calculate wingspan
- Taper/sweep = 0
- Estimation of C_L and C_{D0} as usual

Points to Ponder

- Should HALE aircraft be manned?
- Infinite energy sources?

Manned vs Unmanned

Air to Air Re-fuelling

NASA Helios – Solar HALE Aircraft

NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/gallery/photo/index.html
NASA Photo: ED01-0209-3 Date: July 14, 2001 Photo by: Nick Galante/PMRF
The Helios Prototype flying wing is shown over the Pacific Ocean during its first test flight on solar power from the U.S. Navy's Pacific Missile Range Facility in Hawaii.

QUESTIONS?