Stowarzyszenie Elektryków Polskich

Sekcja Automatyki i Pomiarów Oddziału Warszawskiego

Lotnictwo bezzałogowe - zastosowania i wyzwania na przyszłość w obszarze technologii i bezpieczeństwa

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Politechnika Warszawska, MEiL, ITLiMS

7 Dec 2016, Politechnika Warszawska

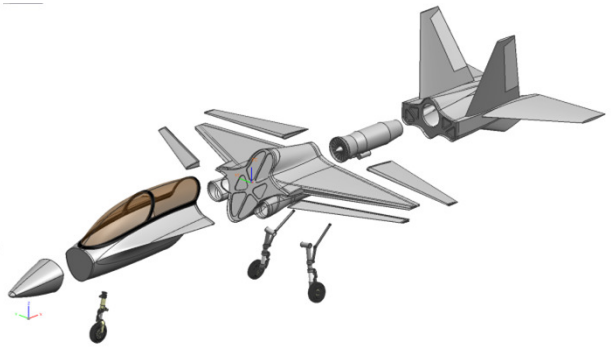
Background and motivation

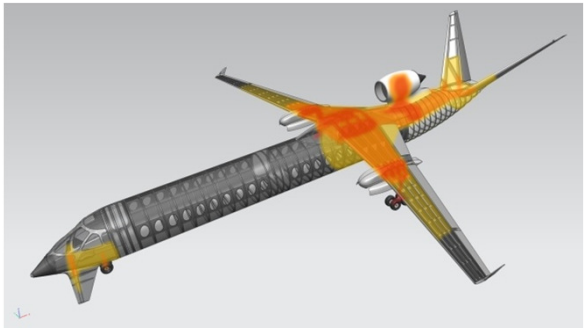
- 25 years of experience in UAV/UAS activity
- Many international research programmes & projects (SAMONIT, NACRE, PW-100, MONICA, …)
- Regular lectures for graduate students at Warsaw University of Technology since 1997

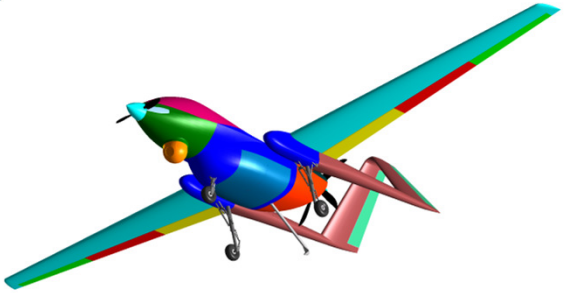
Layout of presentation

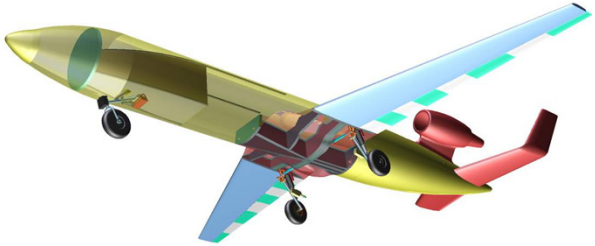
- UAS – state of the art and future challenges
- Important international and domestic projects
- Categories
- Sensors and systems
- Sensitivities to gust and turbulence
- Anti-icing, de-icing
- Requirements and safety issues

Experience - Selected projects



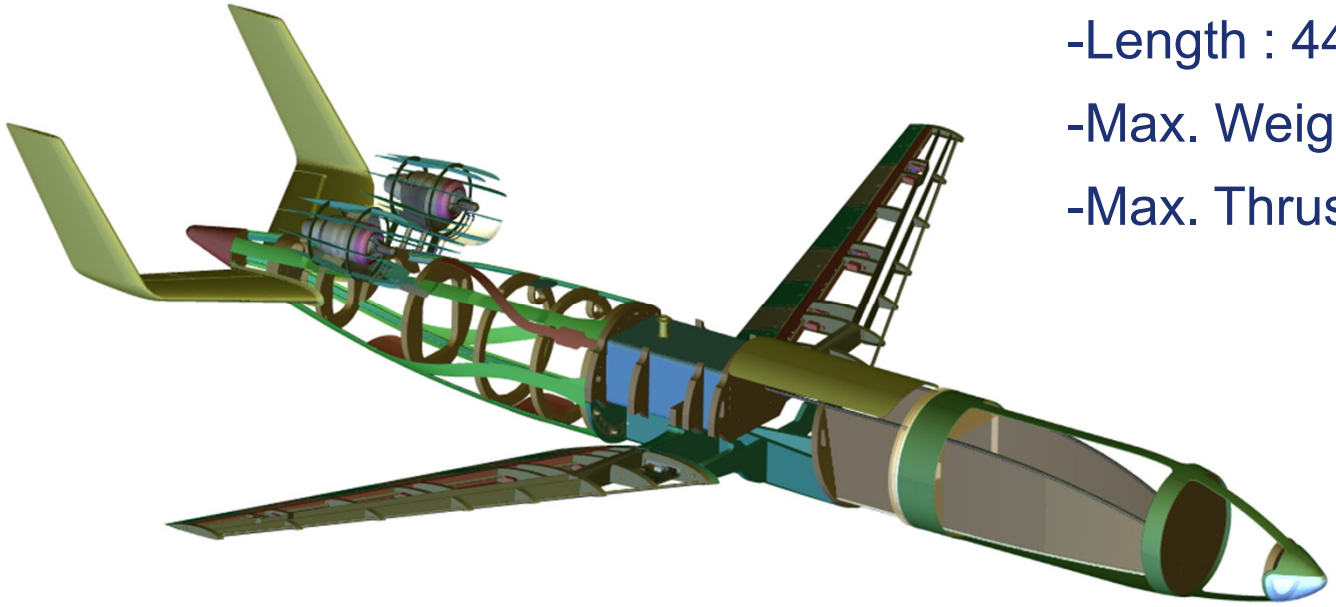






Innovative Evaluation Platform (IEP) Design

- Preliminary Design and Detailed design :
  - Modular Flying Platform Airframe



Main characteristics

-Span : 4160 mm

-Length : 4445 mm

-Max. Weight : 100 kg

-Max. Thrust : 400 N

Property of NACRE consortium

Sizing is based on:

-Froude Similarity

-Operational aspects

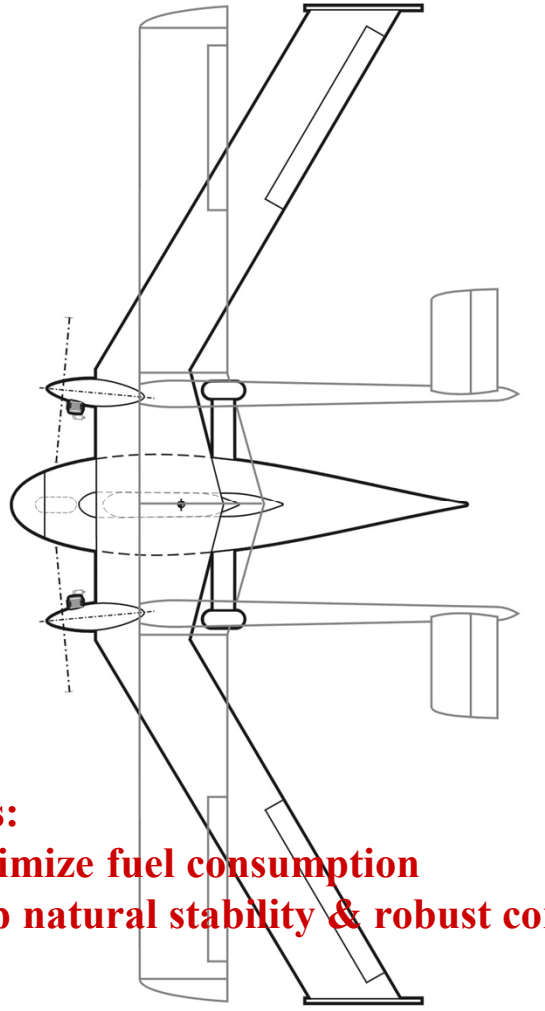
-Available engines

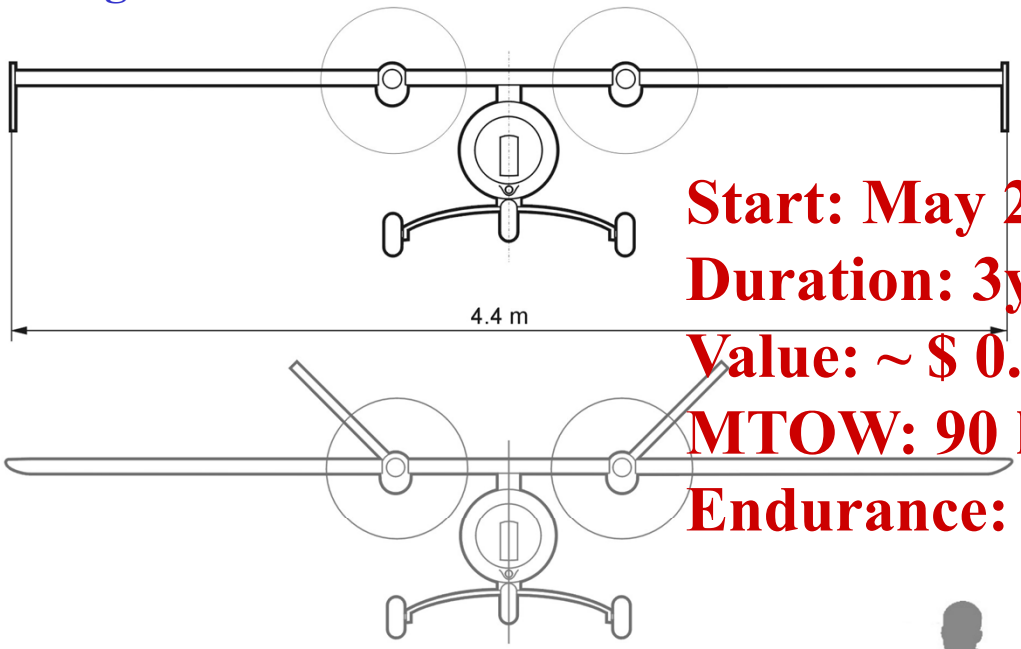
  - Modular Flying Platform Systems (FMCS, Autopilot)
  - Ground Segment

Taxi tests in Modlin, Feb.2010

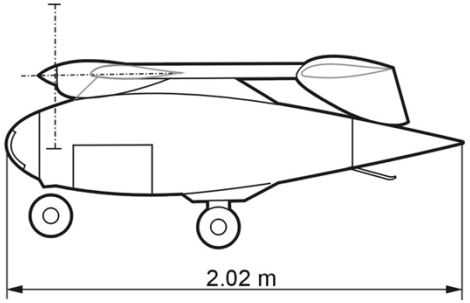
SAMONIT - Polish Research Program For Development of an Advanced Aerial Surveillance System

Classical and tailless configurations under consideration





Start: May 2007
Duration: 3y
Value: ~ $ 0.9 mln
MTOW: 90 kg
Endurance: 24 h



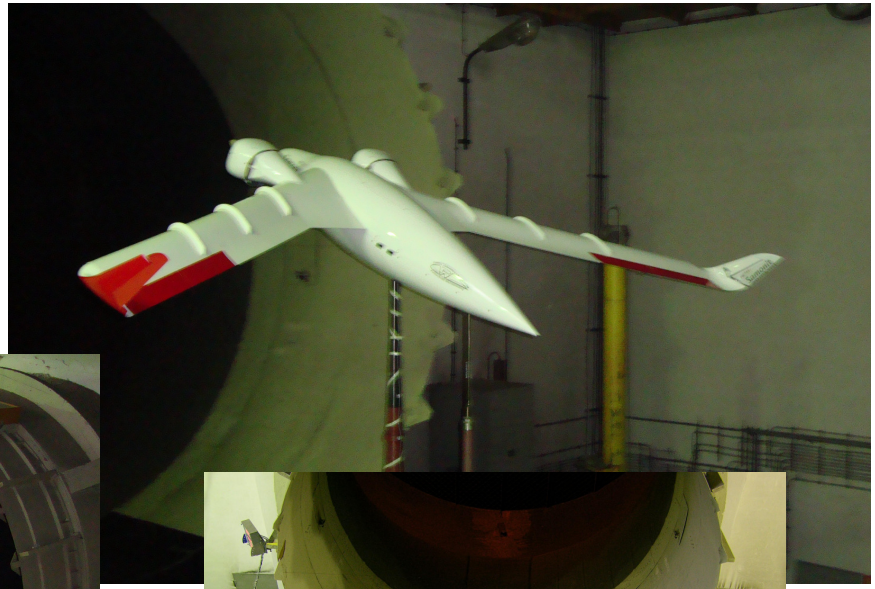
Goals:
- **minimize fuel consumption**
- **keep natural stability & robust control**

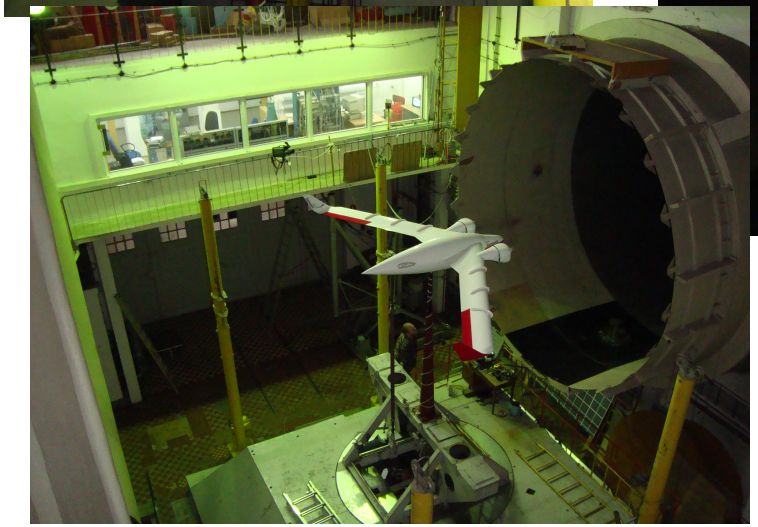
Flight tests – beginning December 9, 2009

Flight tests: Mińsk Mazowiecki, Sochaczew, July 2011

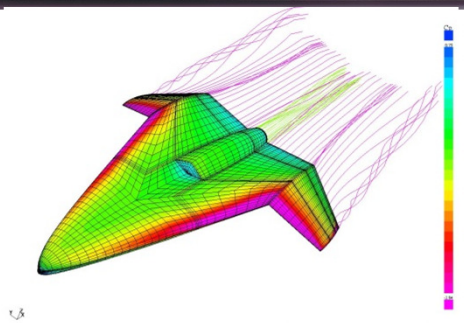
Flight show for MoD, Minsk, July 12, 2011

Wind Tunnels in IoA & PW





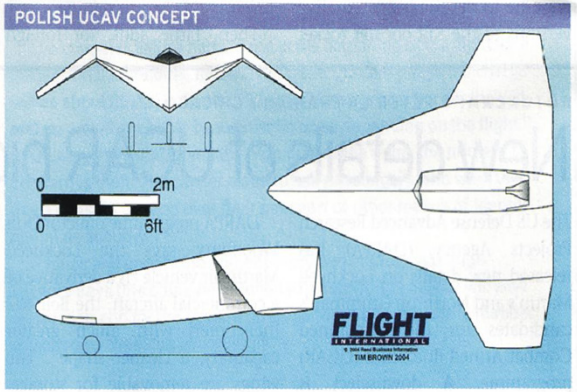
PW-124 – UCAV (Unmanned Combat Air Vehicle)



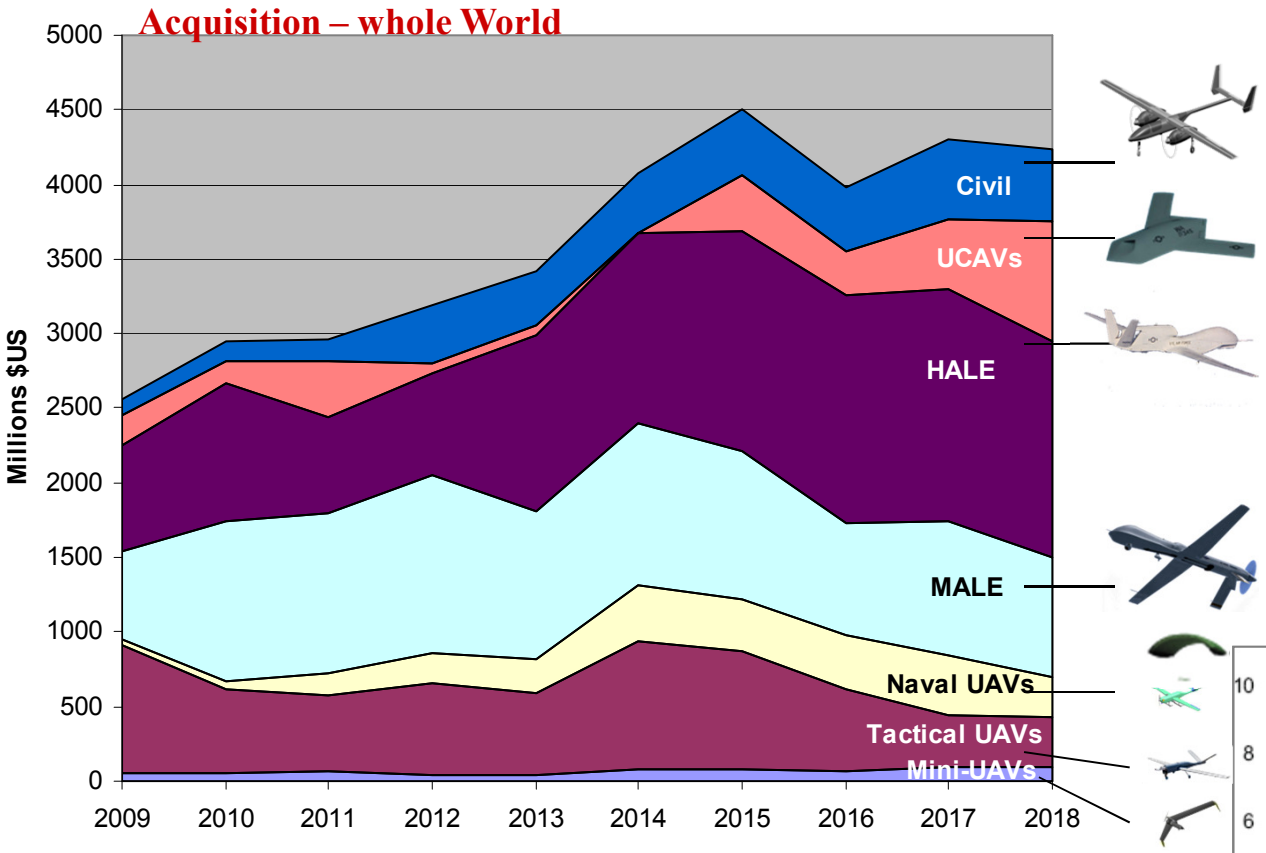
RESEARCH

Polish university reveals concepts for UCAV

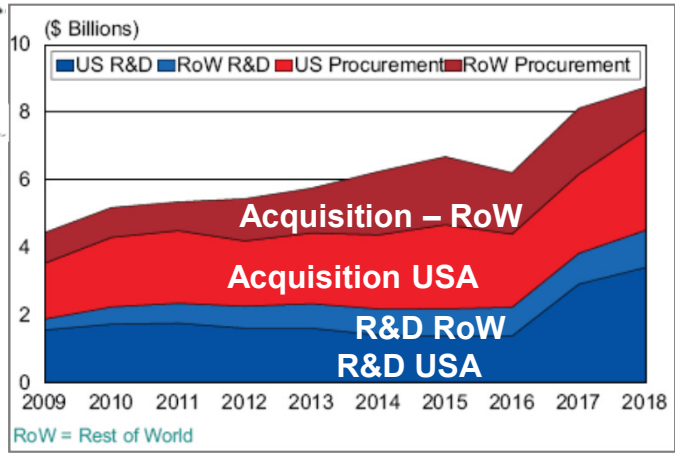
The Warsaw University of Technology has unveiled concepts of what it hopes will be a Polish unmanned combat air vehicle (UCAV). Initial design work has been carried out on an air vehicle designated PW-124 which is proposed as a 700km (380nm) maximum range, high subsonic speed ground-strike system with an endurance of 2.5h. The UCAV would be powered by a Microturbo TRI 60-5 turbojet engine.



UAV Market Development Forecast



Constant Growth in UAV Market and R&D Investments

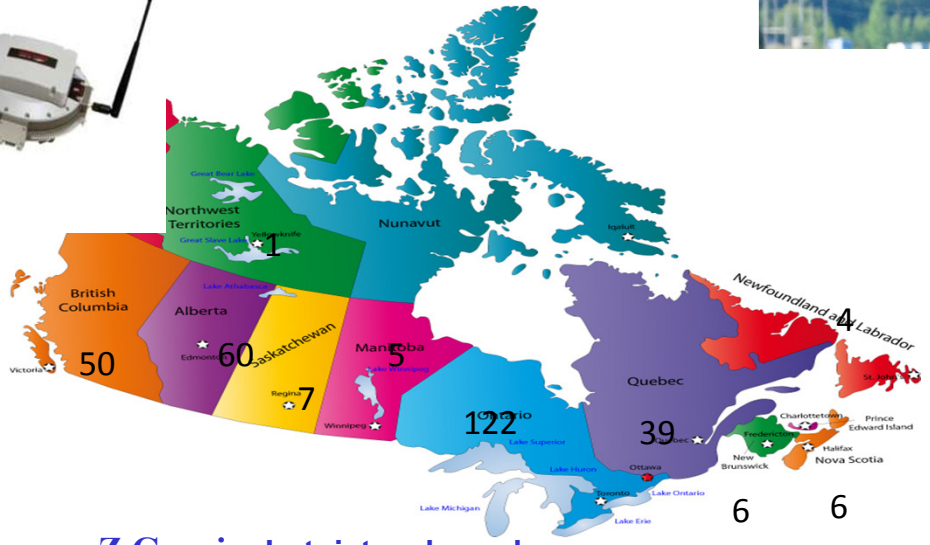


Source:
"WORLD UAV Systems, Market profile & Forecast", Teal, 2009

Canadian UAS Industry

From dr Iraj Mantegh,
NRC - Civil UAS Program Team,
Presented at AeroDays, London

- Over 312 companies, primarily SMEs
- UAS operations have seen close to a 10-fold growth in the five years since 2008
- Significant increase (%485 over 2 years) in No. of flight certificates (SFOC) for Visual Line of Sight (VLOS)



From dr Iraj Mantegh,
NRC - Civil UAS Program Team,
Presented at AeroDays, London

SAA (See & Avoid) Objective

NRC is investigating autonomous, local approaches to SAA:

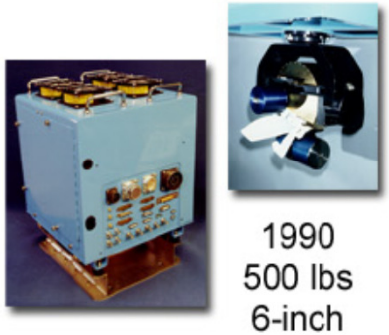
- **Cooperative, non-cooperative, active, passive**
- **Low mass, low power**

Target Specifications:

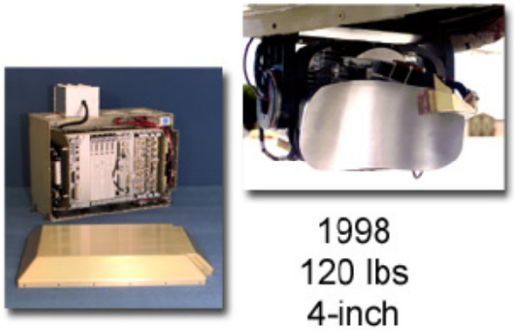
- Aircraft: **25 kg light UAS**
- Mass: < 5 kg
- Range: **Visual and BLOS**
- Airspace: Class G, Terminal
- Field-of-Regard: 240 x 30 degrees

Pico & Mini SAR - Progress

Sandia SAR – development & miniaturization

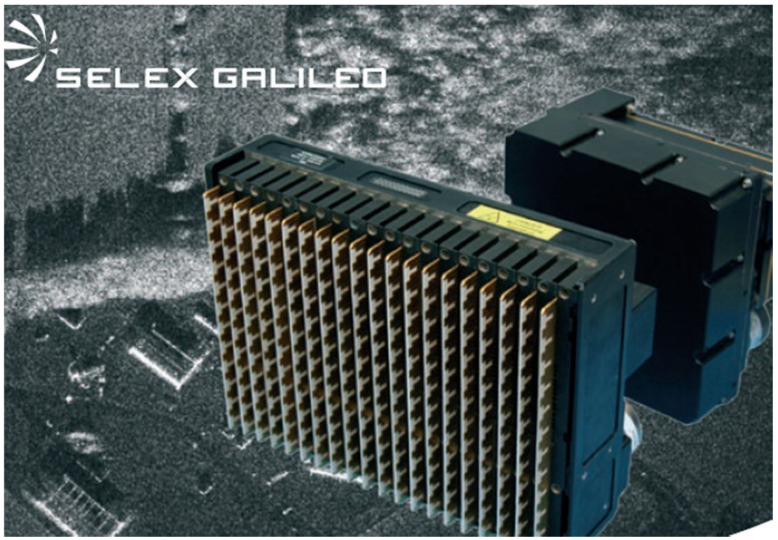


1990
500 lbs
6-inch
resolution



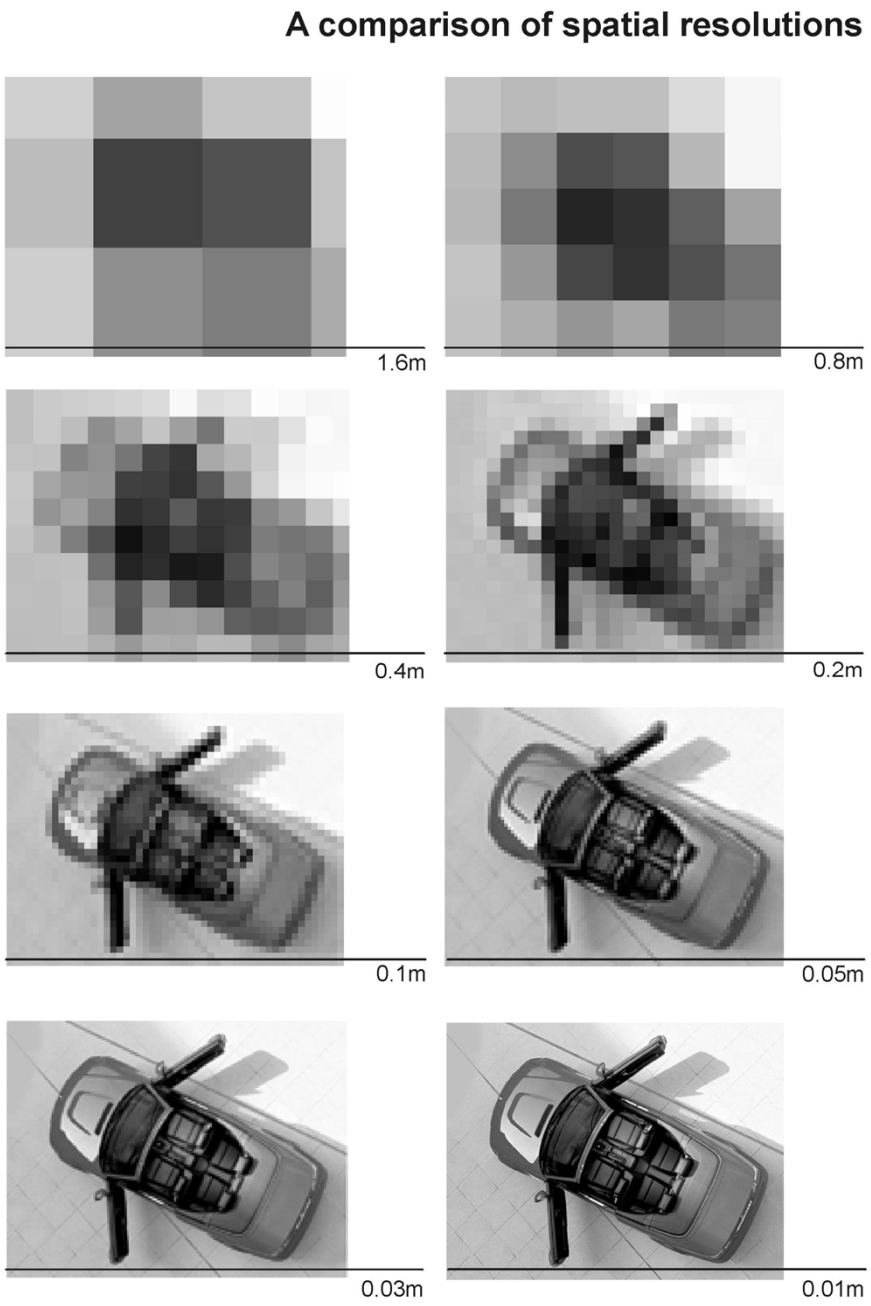
1998
120 lbs
4-inch
resolution

2005
27 lbs
4-inch
resolution



Weight 21 lbs
40 inch resolution

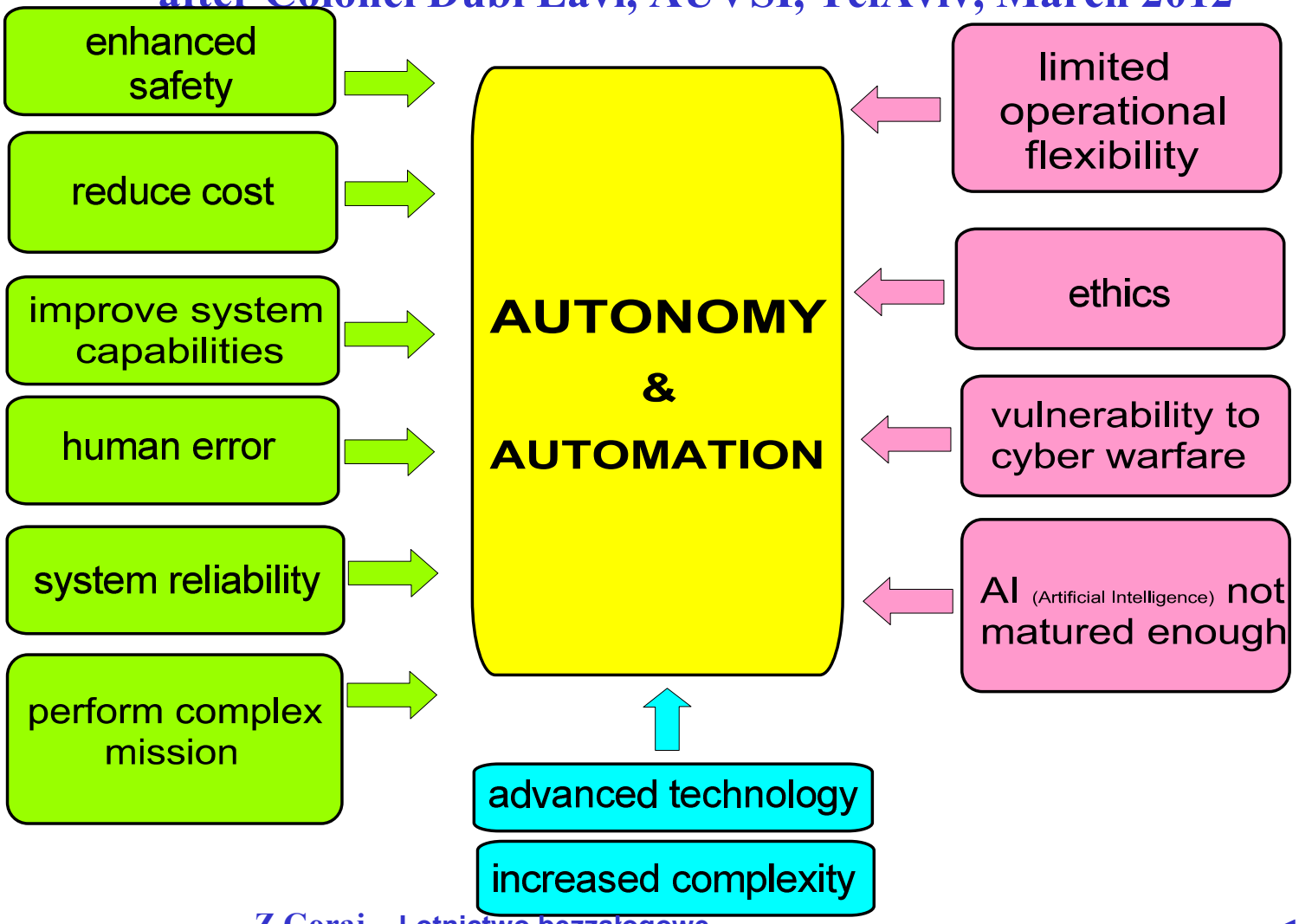
Modes:
Strip SAR
Spotlight SAR
GMTI



SAR (LYNX) resolution

Drivers for autonomy in systems

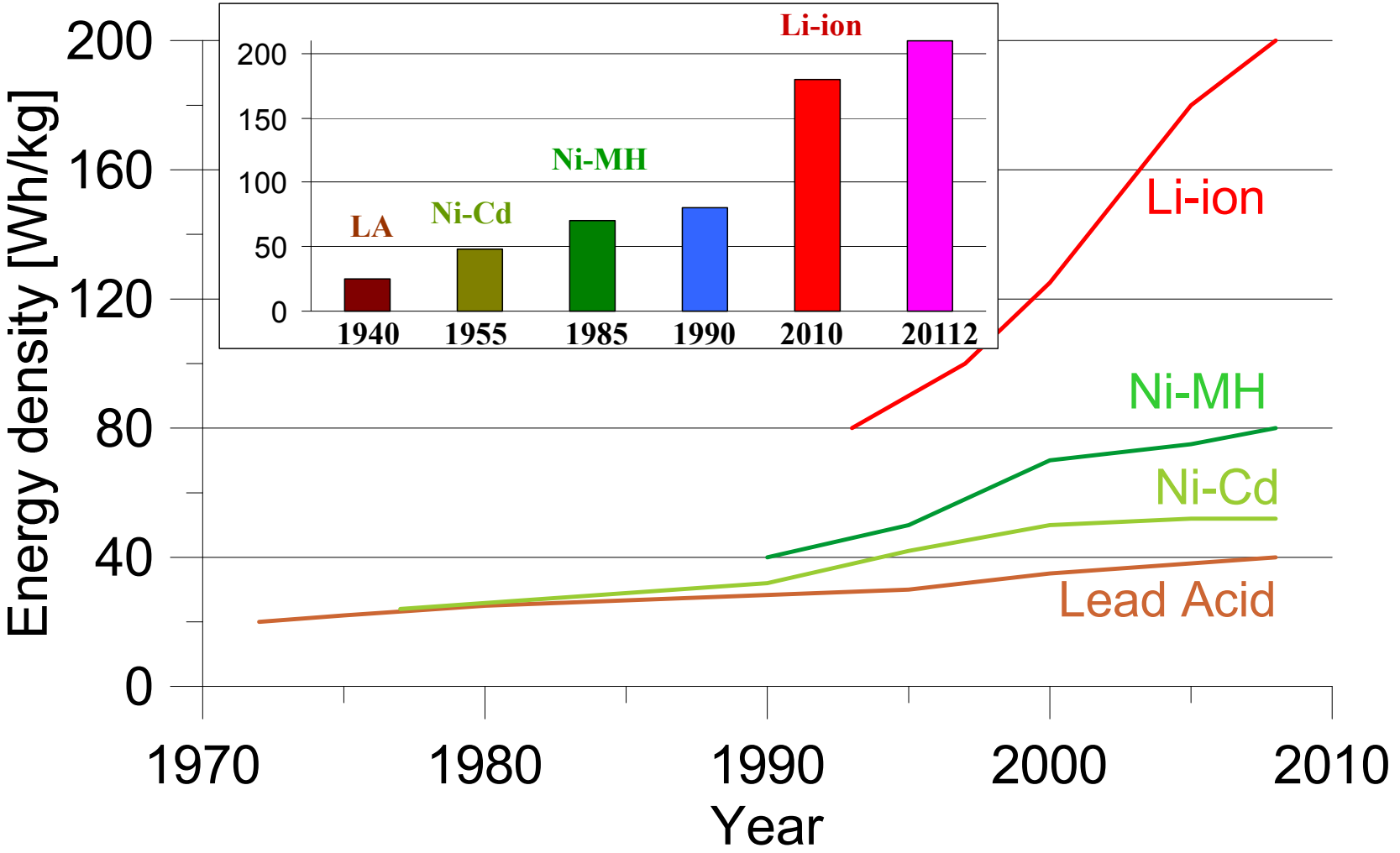
after Colonel Dubi Lavi, AUVSI, TelAviv, March 2012



Are we ready for autonomy?

- **Current systems include advanced level of automation;**
- **Technology and ethics are significant drivers to achieve autonomy. They act in opposite directions;**
- **We are not ready for autonomy yet!**

Progress in batteries technologies



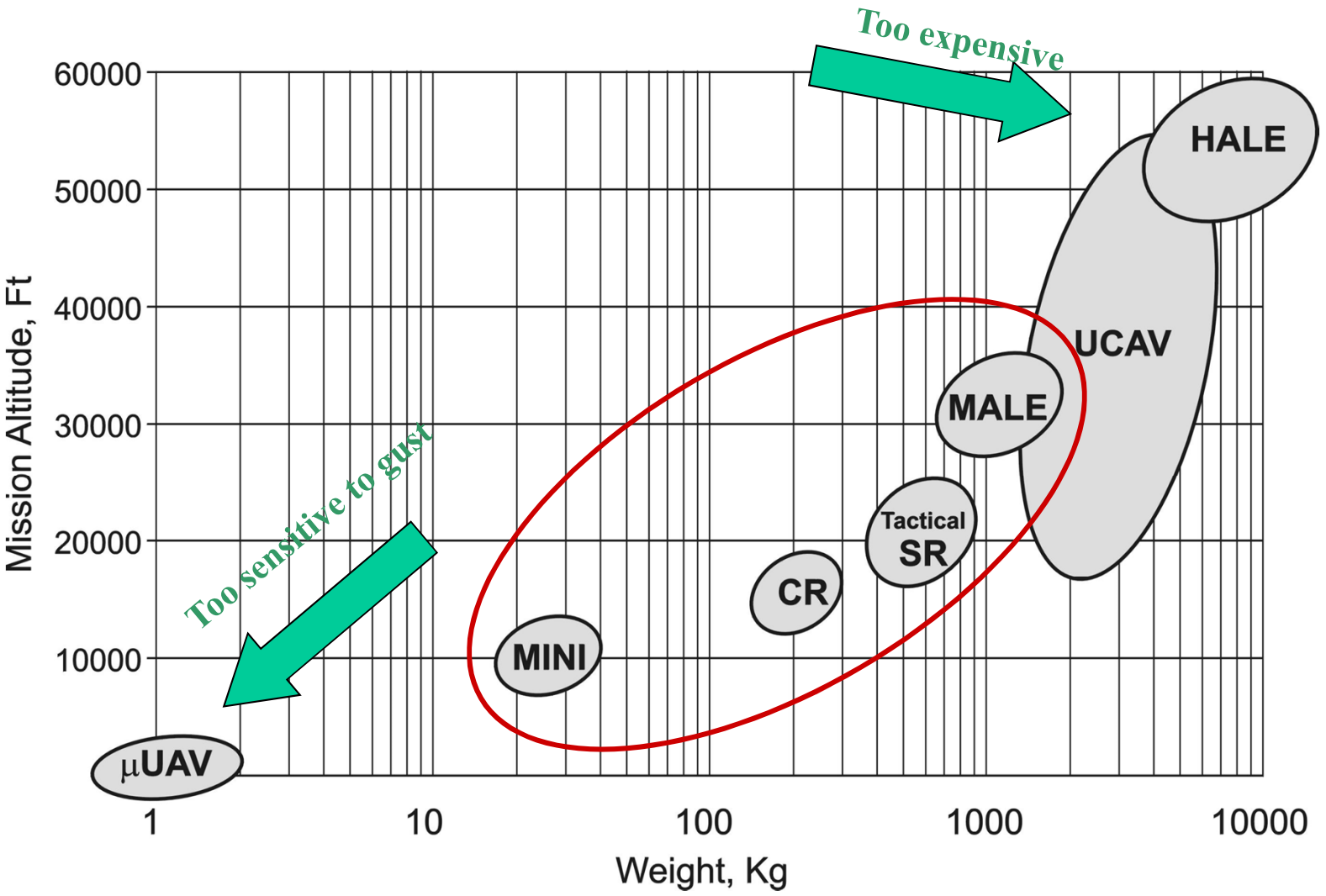
Lithium-ion technology is now the limiting factor

- A kilogram of petrol contains about **13,000 Watt-hours** of chemical energy – of which **about 4,500 Watt-hours might be captured by an internal combustion engine.**

- But a kilogram of today's **lithium-ion battery stores only 100 Watt-hours** of electricity.

- Cost a part, for the same amount energy, today's **lithium-ion batteries are 45 times heavier (and 16 times bigger) than petrol**.

Classification



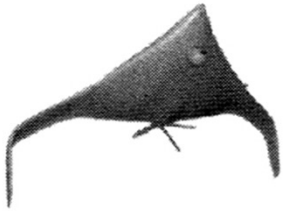
Manufactures usually offer families of UAVs, each with similar configurations and design features

Navmar Tigershark

W_{TO}	285 lbs
W_{PL}	30 lbs
Span	17 ft

Navmar Mako

W_{TO}	140 lbs
W_{PL}	30 lbs
Span	12.7 ft



Swift Killer Bee 3

W_{TO}	95 lbs
W_{PL}	15-30 lbs
Span	9.2 ft

Swift Killer Bee 2

W_{TO}	43 lbs
W_{PL}	7-15 lbs
Span	6.5 ft

BAI Viking 400

W_{TO}	493 lbs
W_{PL}	60 lbs
Span	20 ft

BAI Viking 100

W_{TO}	150 lbs
W_{PL}	20 lbs
Span	12 ft

Griffon Broadsword

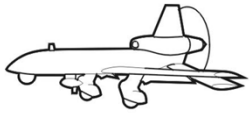
W_{TO}	550 lbs
W_{PL}	120 lbs
Span	22.5 ft

Griffon Outlaw

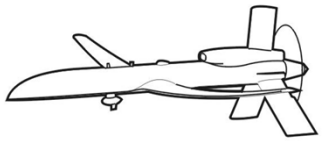
W_{TO}	120 lbs
W_{PL}	40 lbs
Span	13.5 ft

after Jay Gundlach

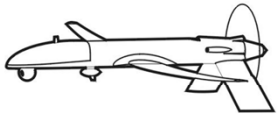
General Atomics – a good example of the family for different surveillance application



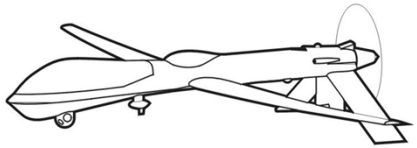
Prowler II
Tactical



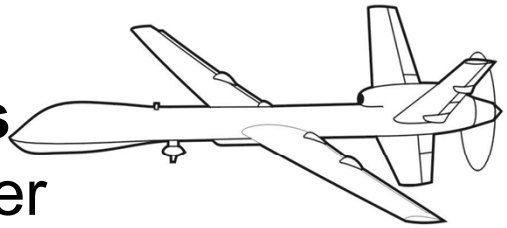
Altus
High Altitude
Atmospheric
Research



I-GNAT
Tactical Long
Endurance



Predator
Medium Altitude
Long Endurance



Predator B
High Altitude
Strategic UAV

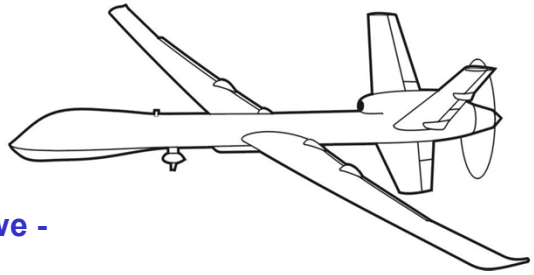
Common features

Rear engine/propeller

High aspect ratio wings

Canted tails

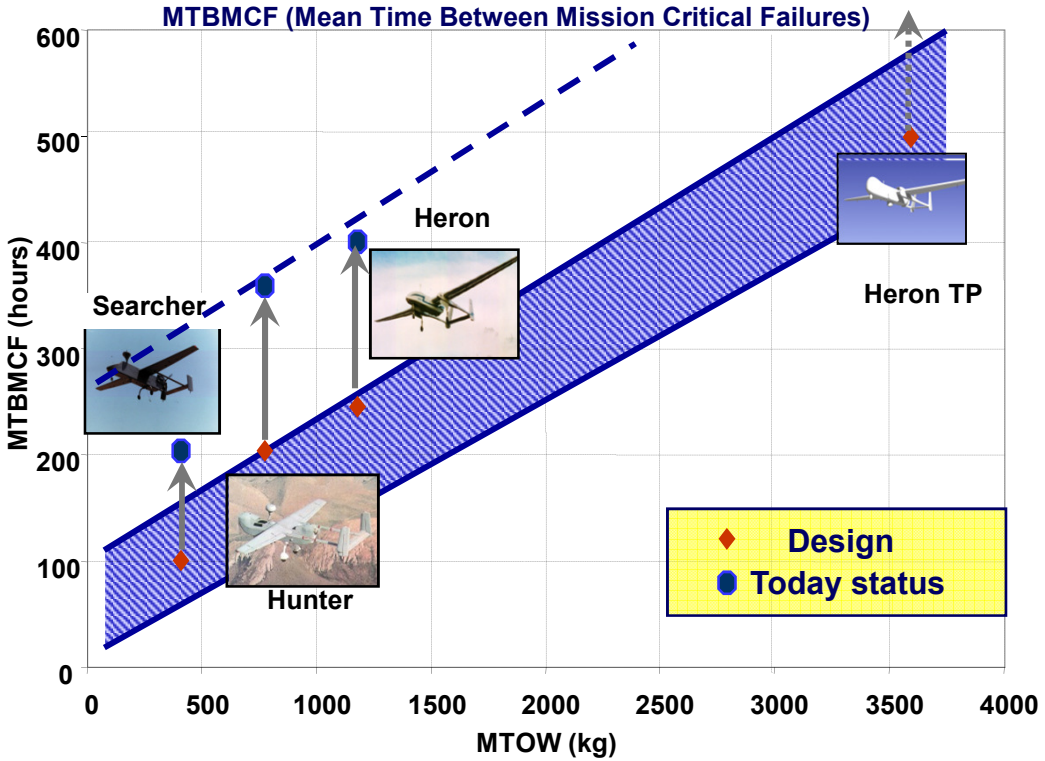
Retractable landing gear

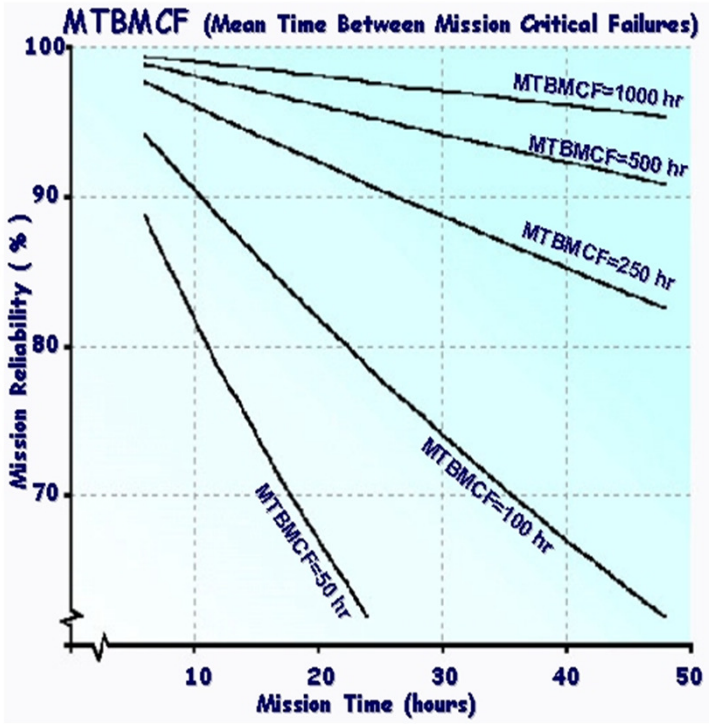


ALTAIR
High Altitude
Scientific
Research

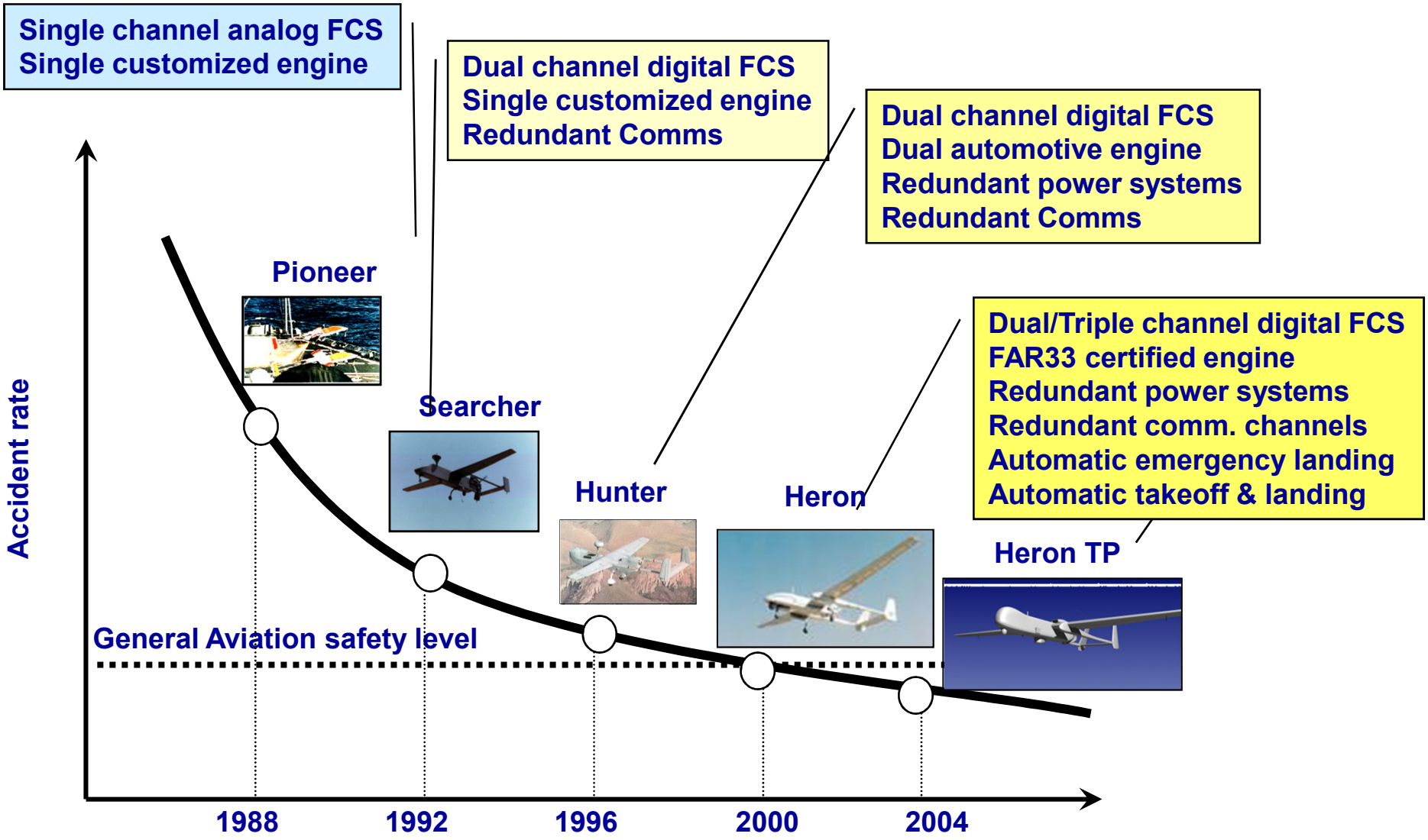
UAV Mission Reliability

- Mean Time Between Critical Failures (**MTBCF**) of UAVs improves with operational time following maturity.
- Hunter is approaching about 400 hours, which translates to about 98% mission reliability for a 12 hr designed endurance.

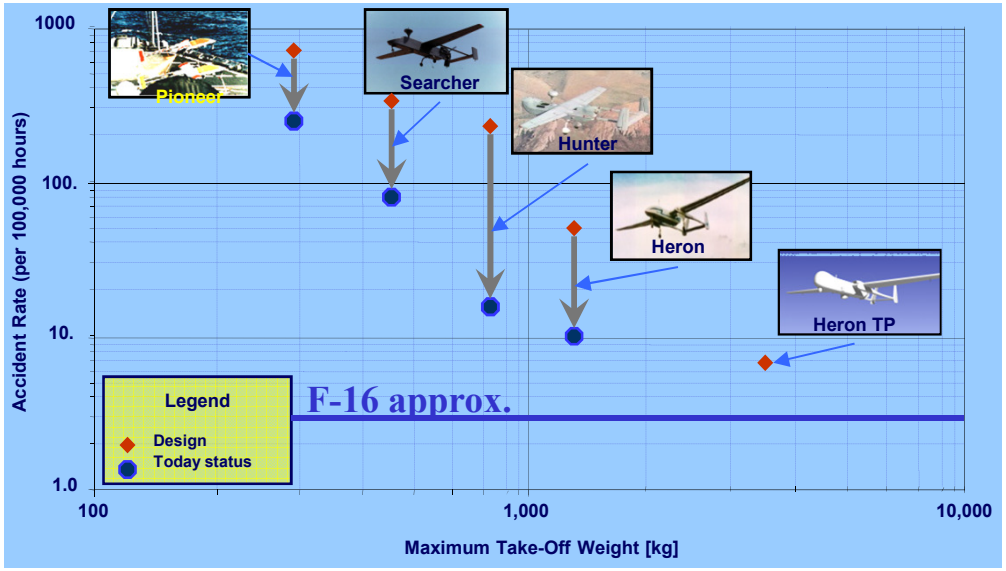


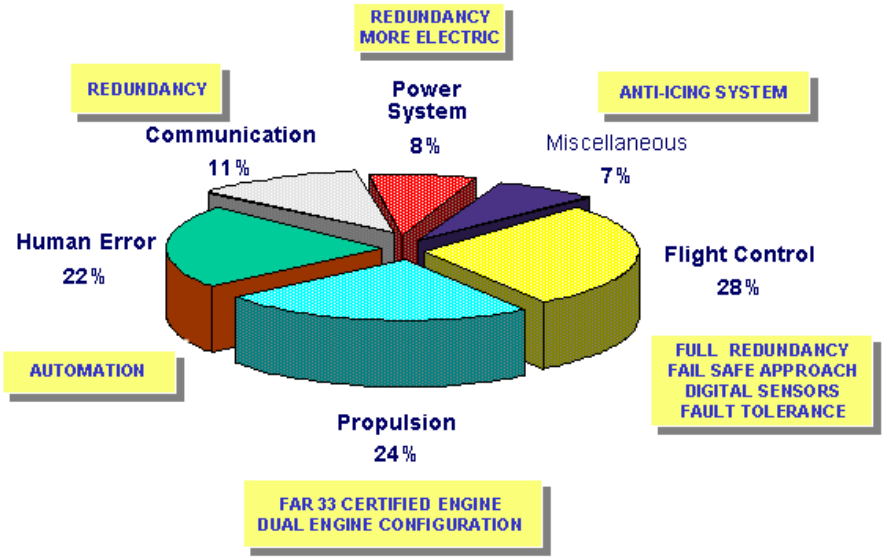


Flight Safety Evolution



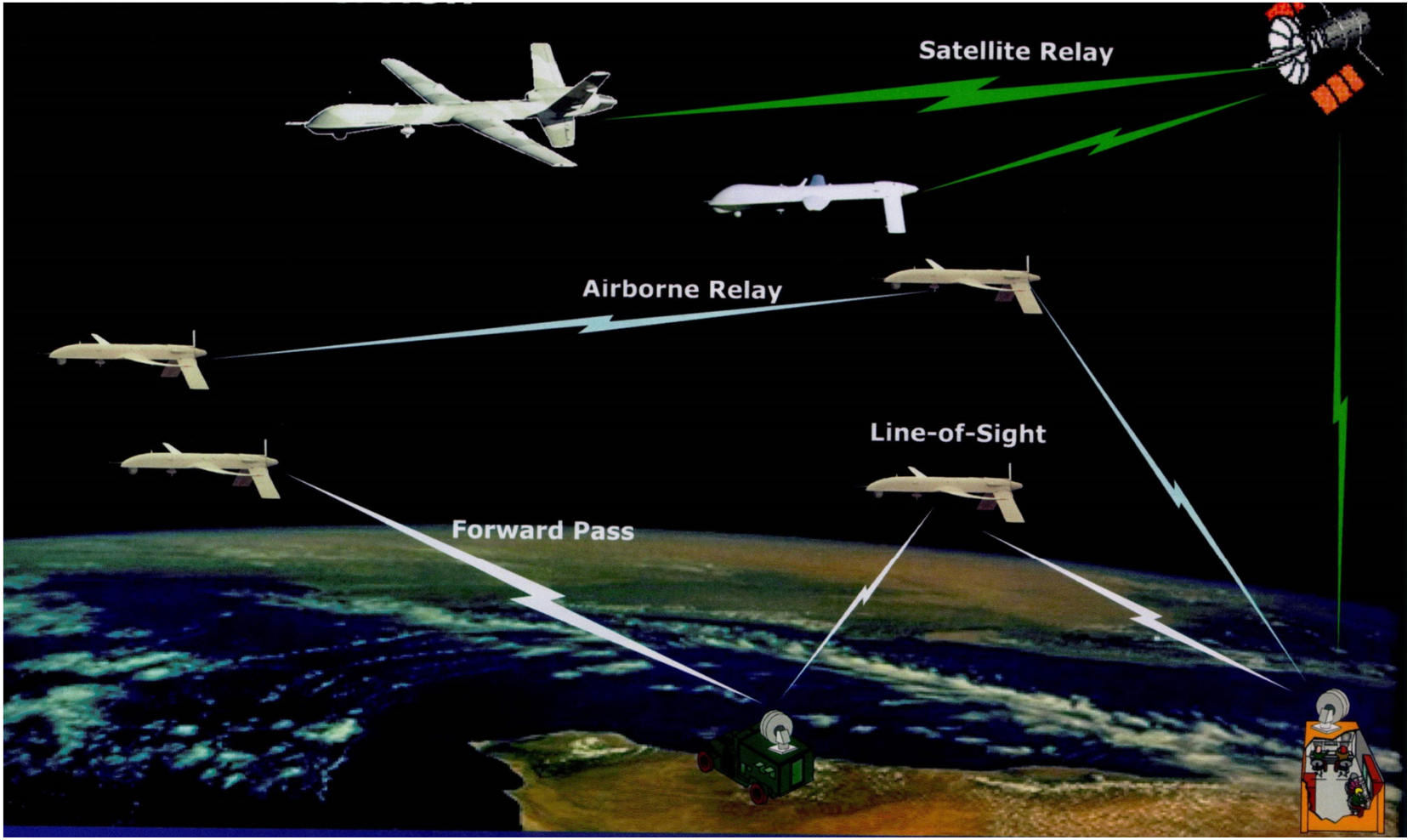
UAV Safety



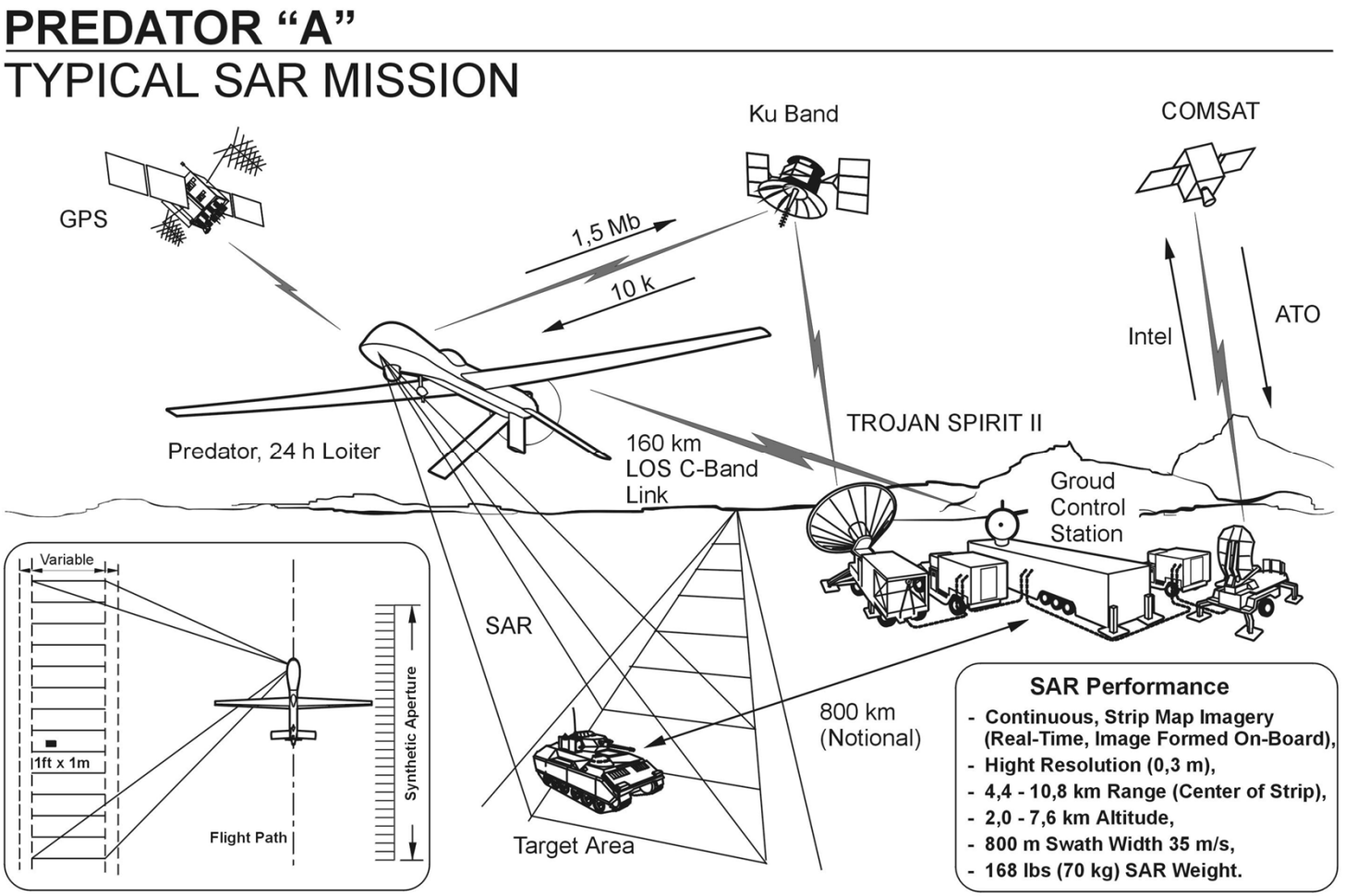


- UAV system must be viewed in its entirety – Air vehicle, ground control station / MMI and communications data link.
- The safety approach should be based on existing airworthiness and safety design criteria for manned aircraft, modified and tailored to UAV specific features and types of operation.

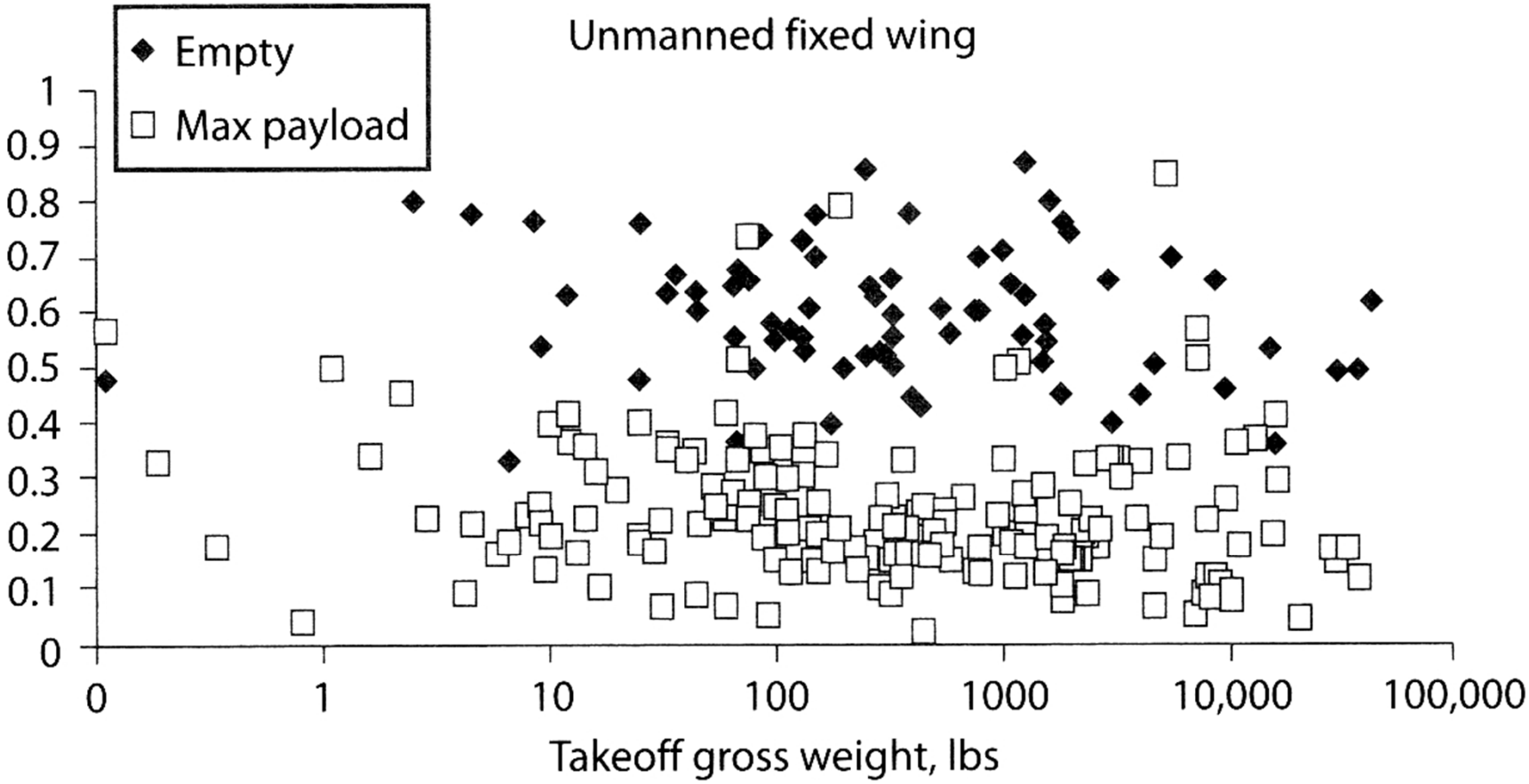
Link-up, link-down



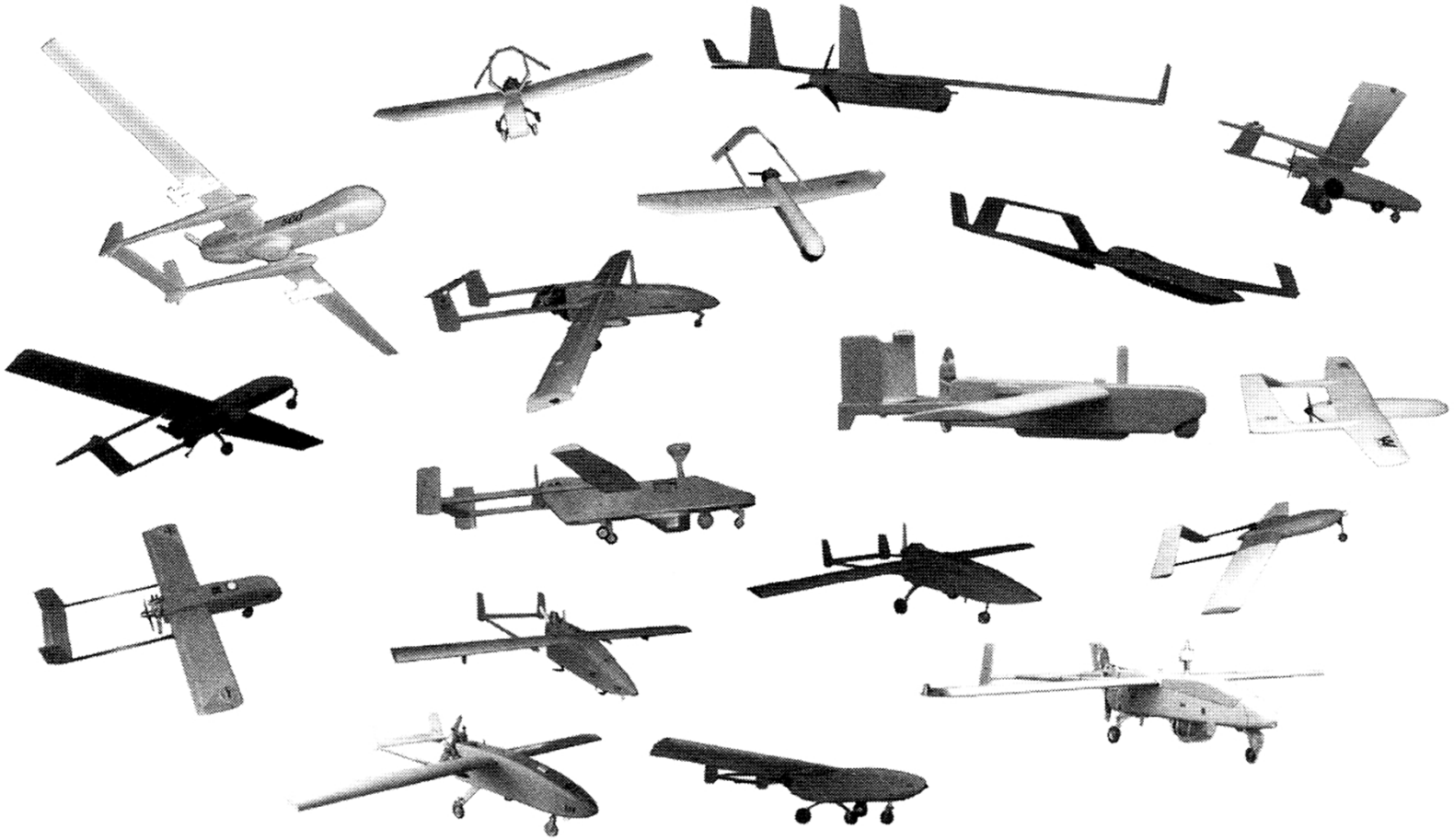
Surveillance mission by typical MALE UAV



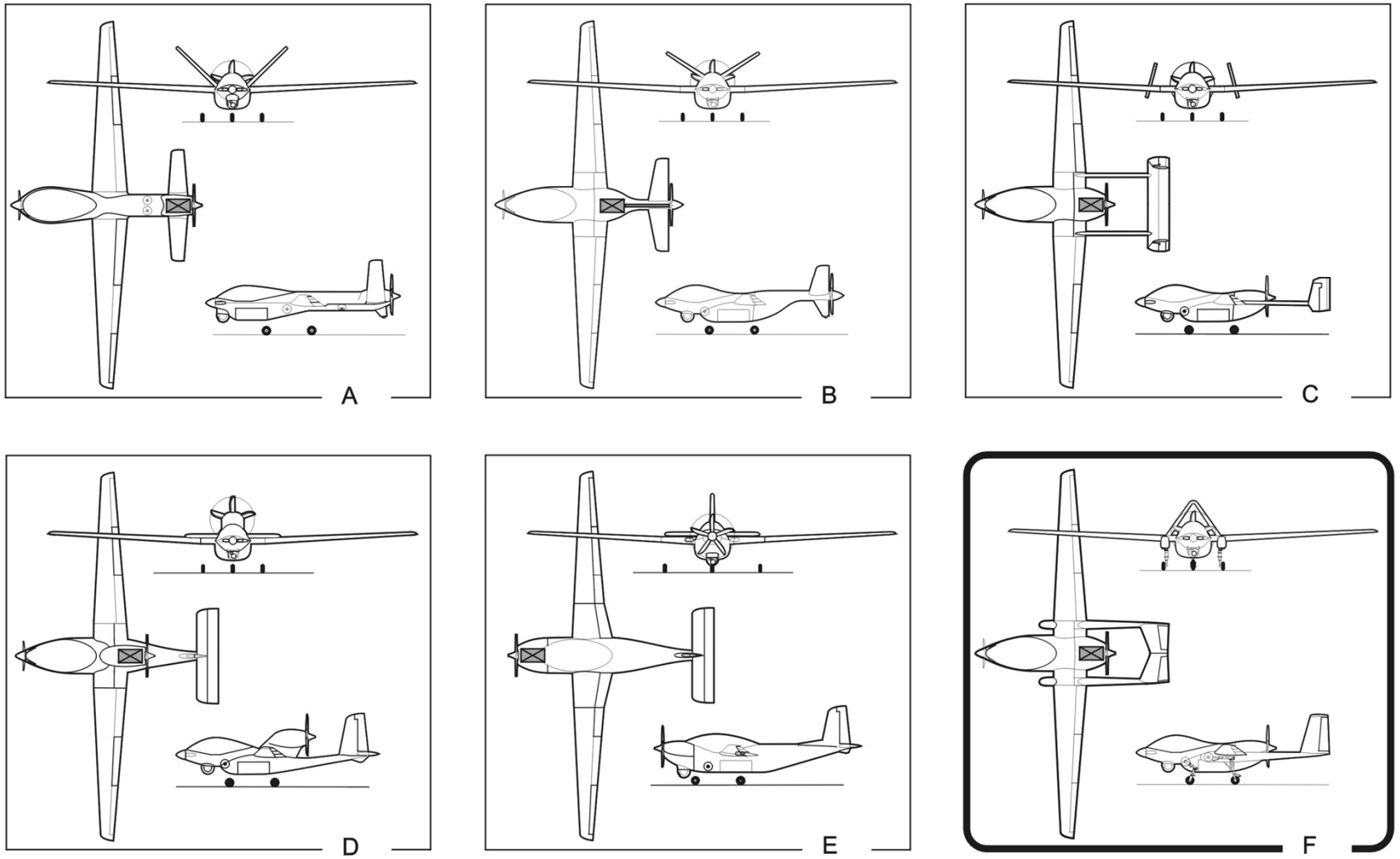
Empty & maximum payload mass fractions for fixed-wing UAVs



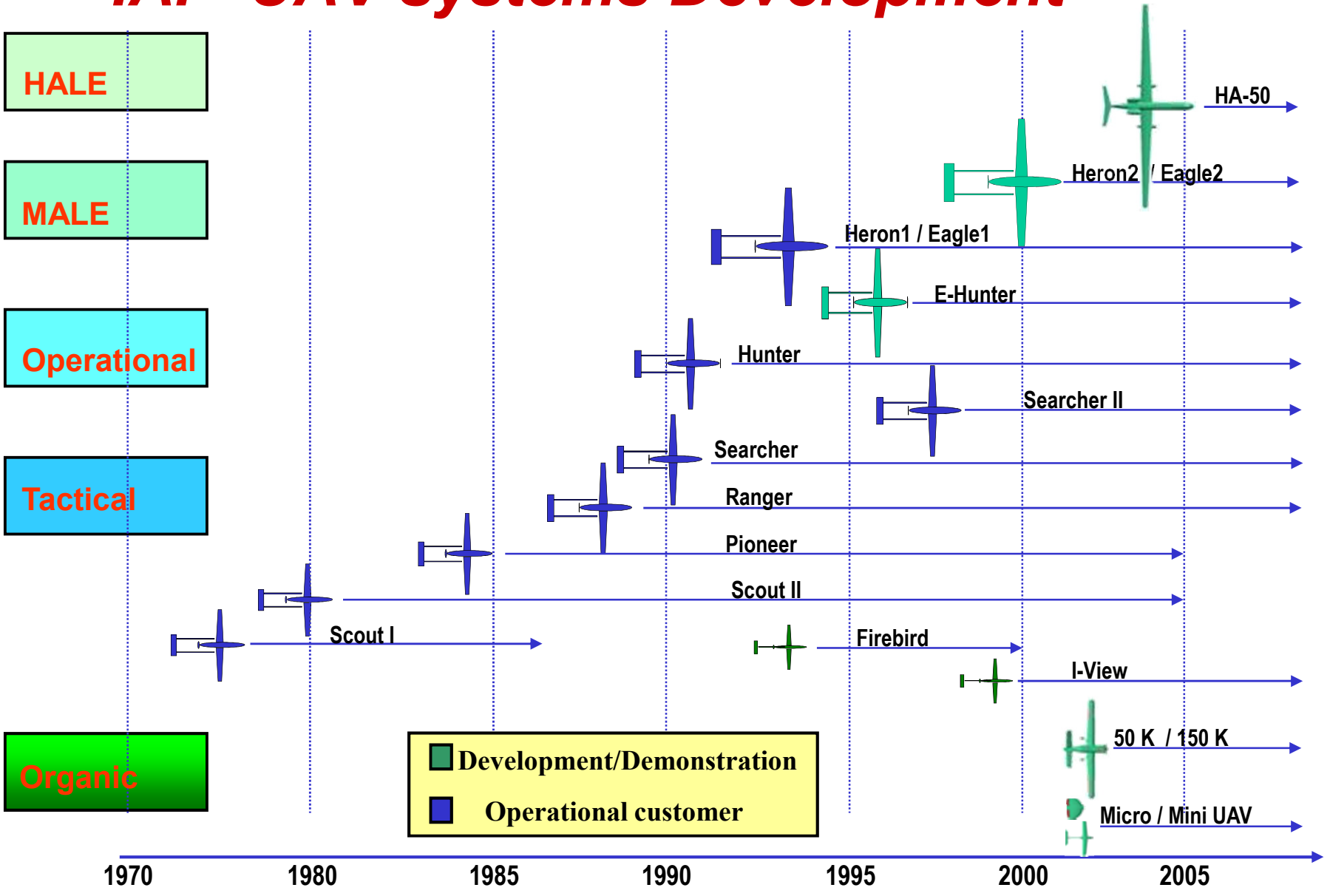
Conventional twin-boom pushers are very popular



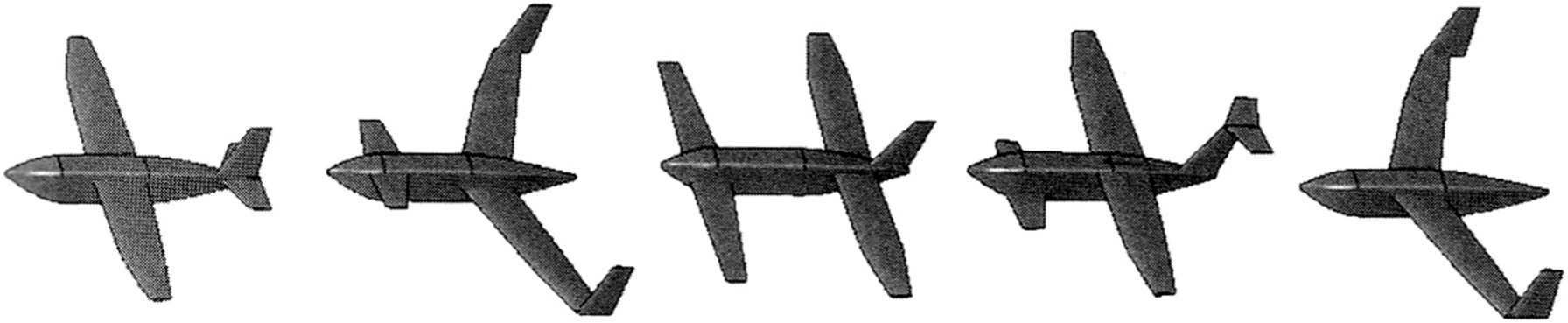
Why 2-booms, pusher configuration is so popular?



IAI - UAV systems Development

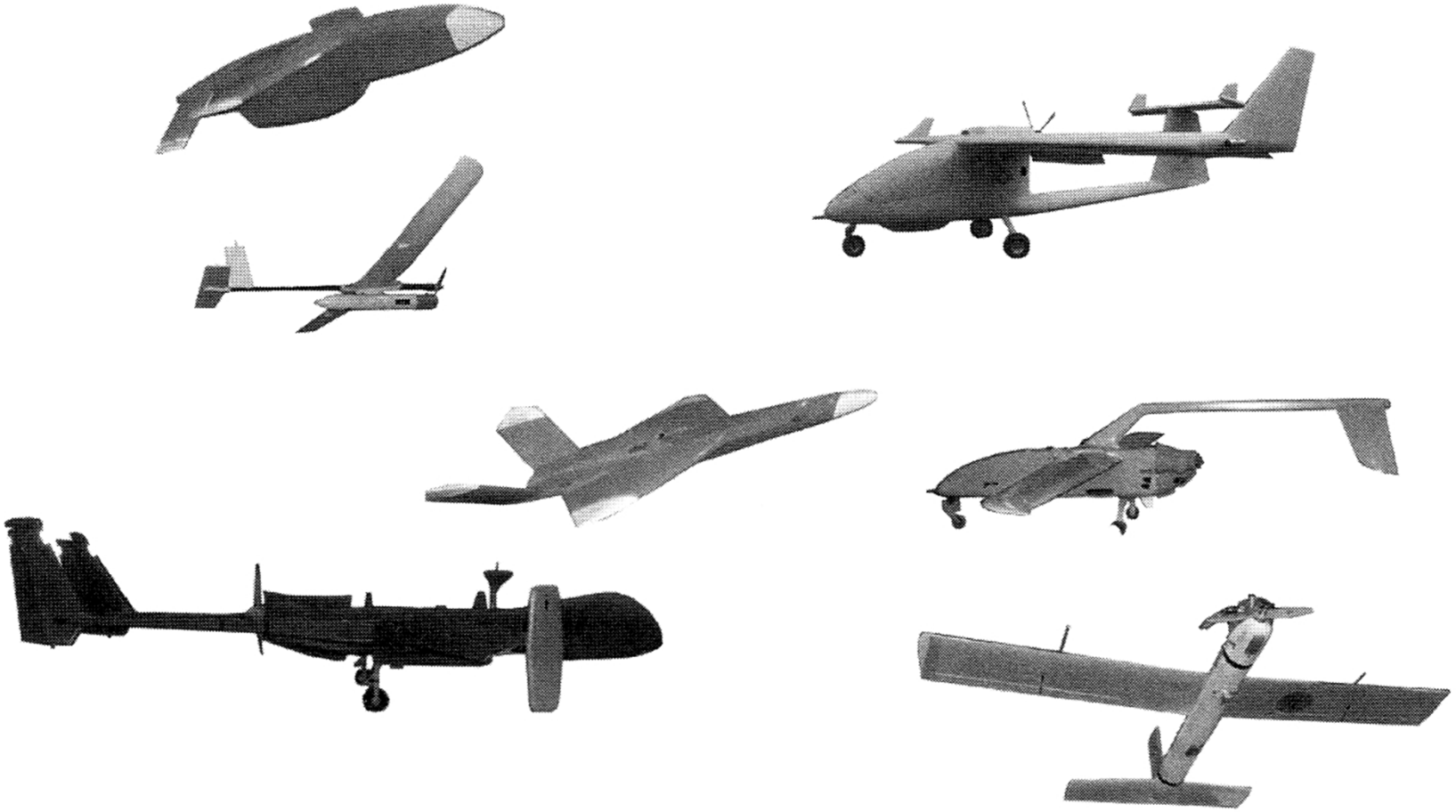


Primary wing system configuration

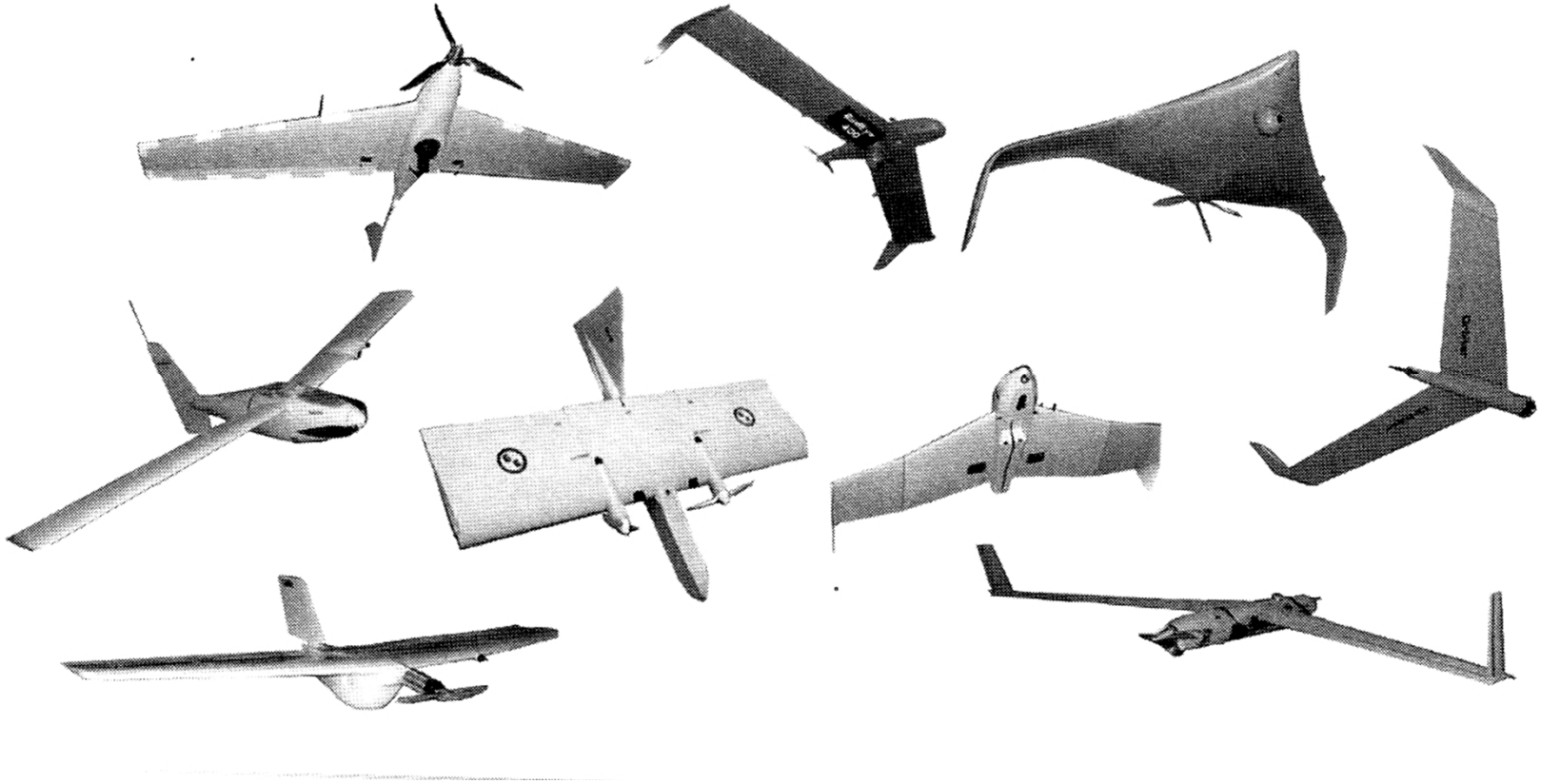


DraganFly TANGO

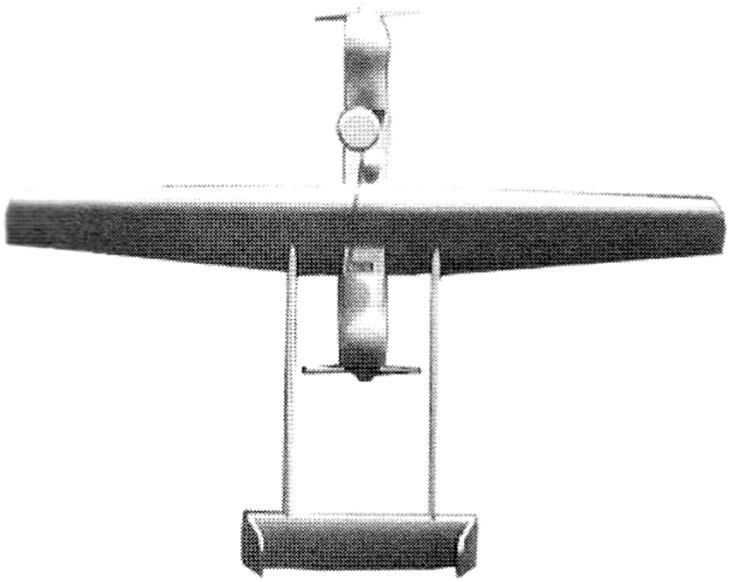
Conventional system configuration - examples

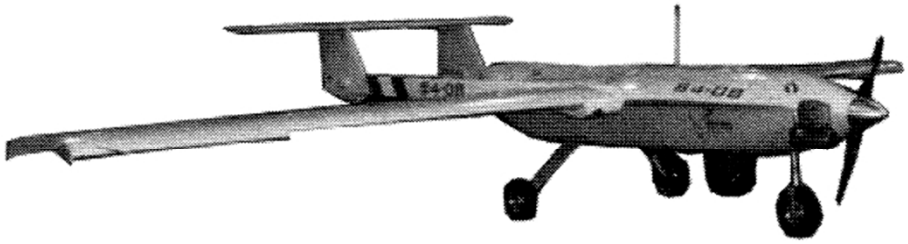


Flying wing UAVs

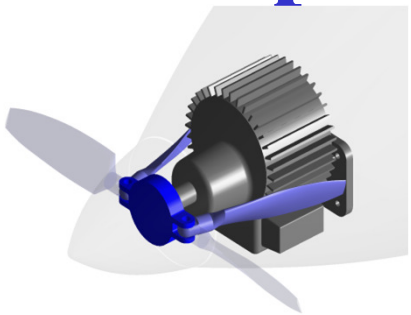


Push-pull engine designs

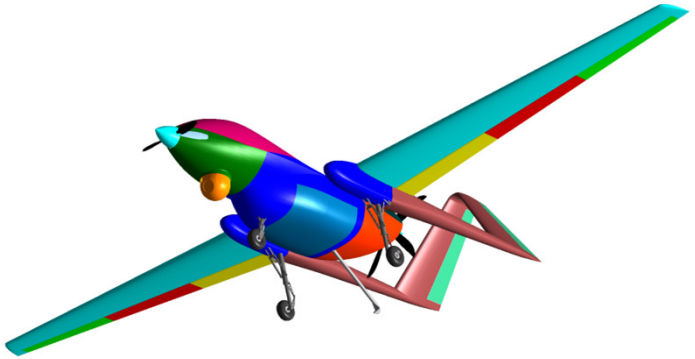




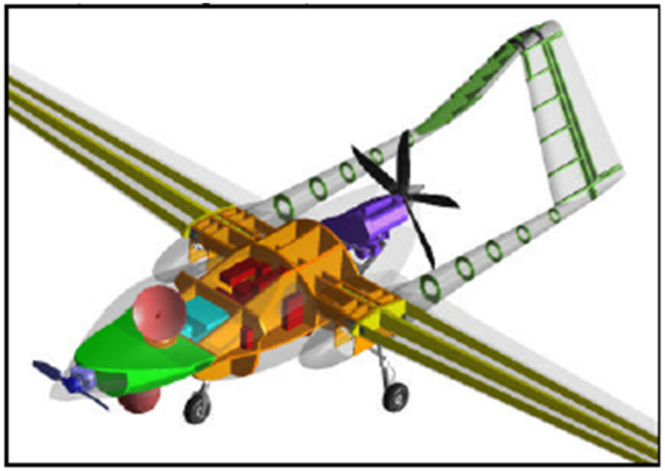
Push-pull-redundant engine design



Maximum Takeoff Weight	930kg
Basic Empty Weight	488 kg
Fuel Weight	225 kg
Payload Weight	*217* kg
Span	12.6m
Reference Area	10.22m^2
Propulsion Type	Piston
Propulsion	TAE 125
Flight Altitude	***20*** kft
Total Endurance	*42* hr

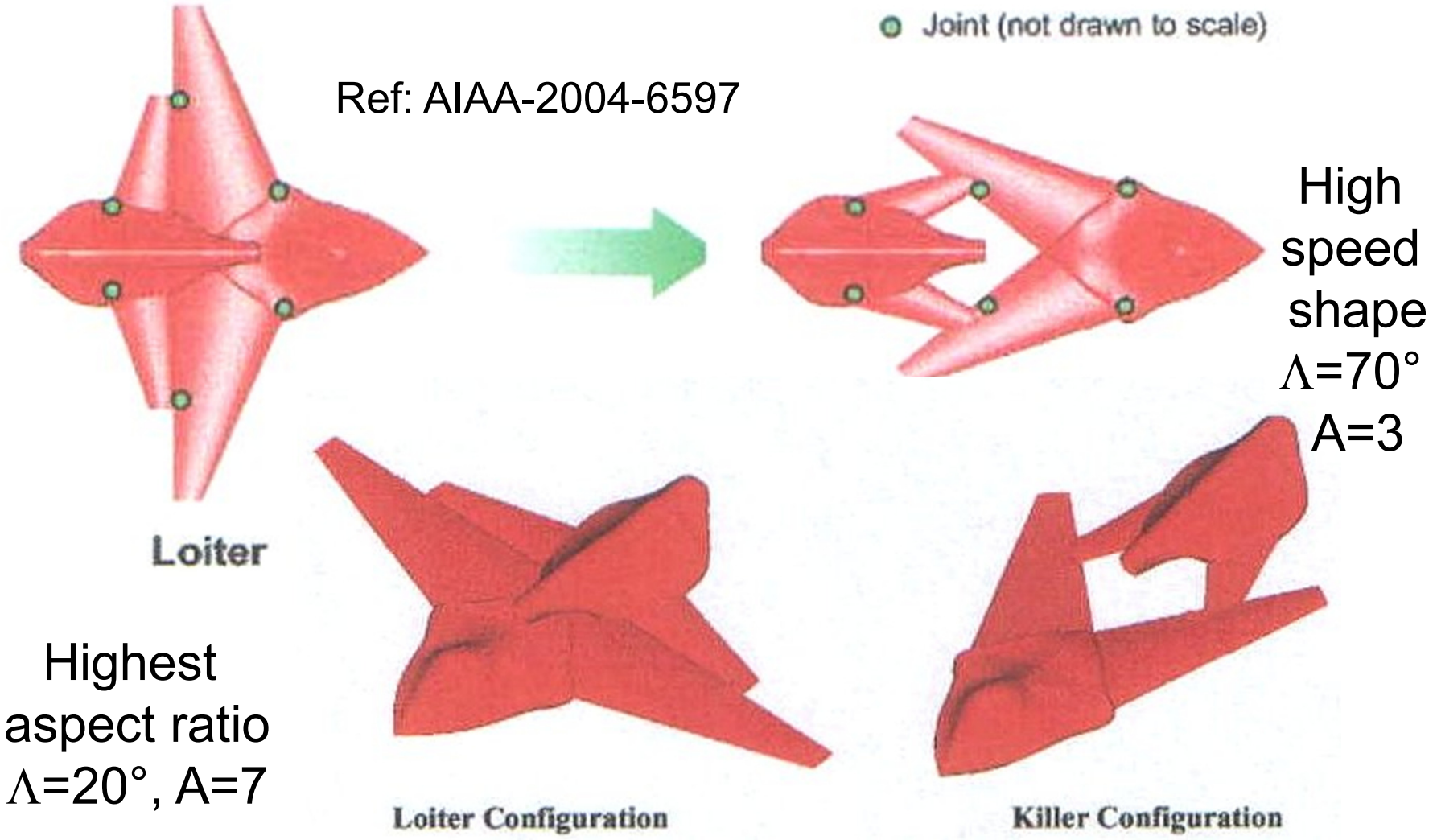


WUT PW103 Configuration

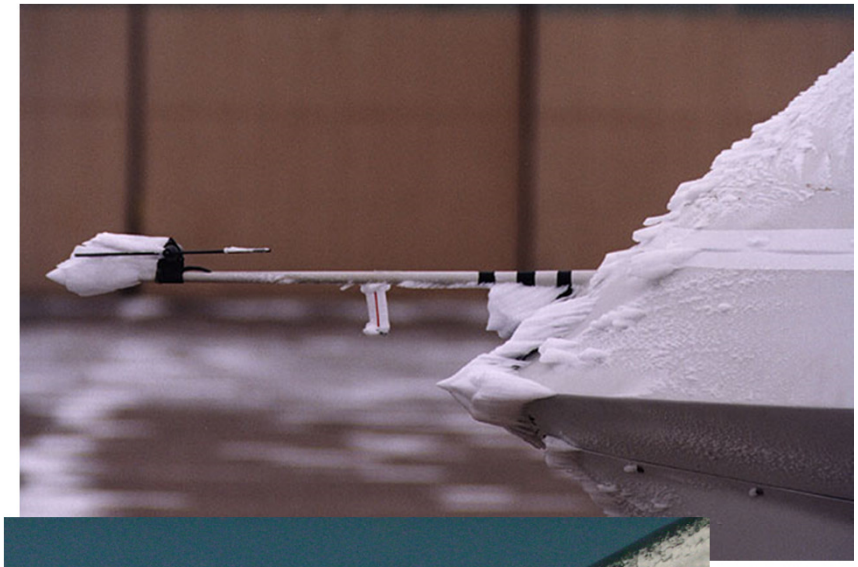


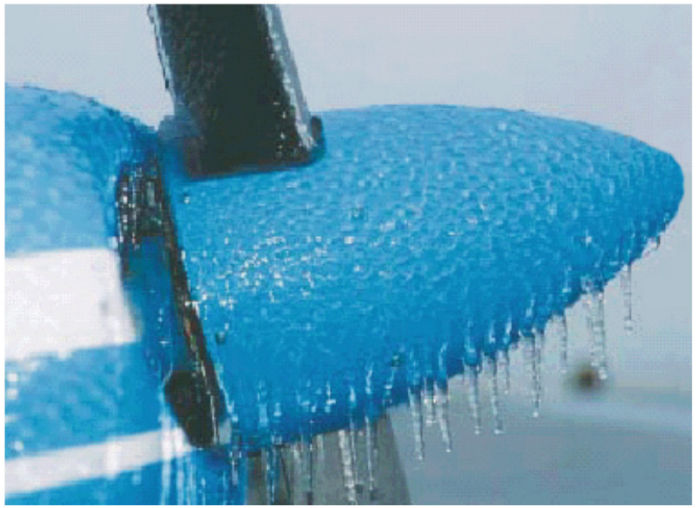
WUT PW103 Internal Layout

Morphing vehicle (multi-role)

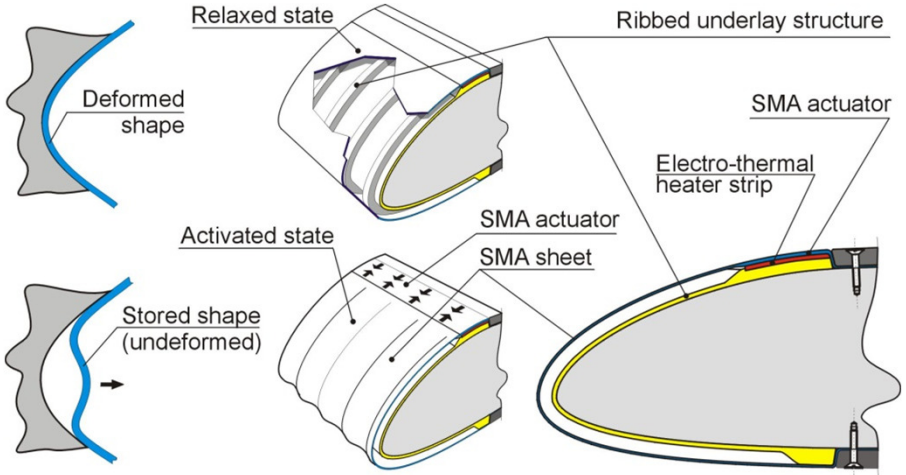


Icing – serious hazard for any UAV



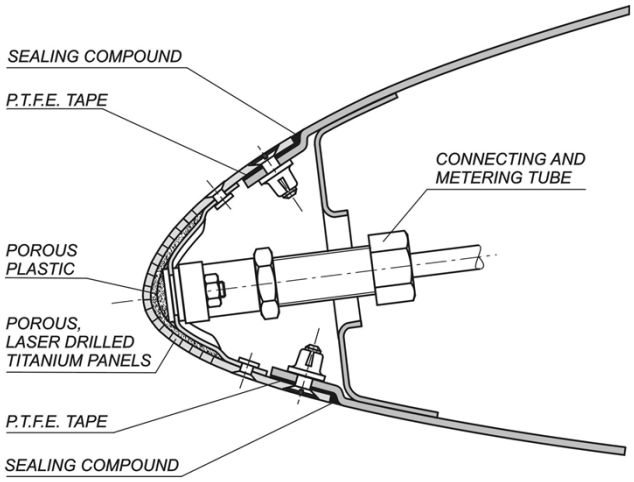


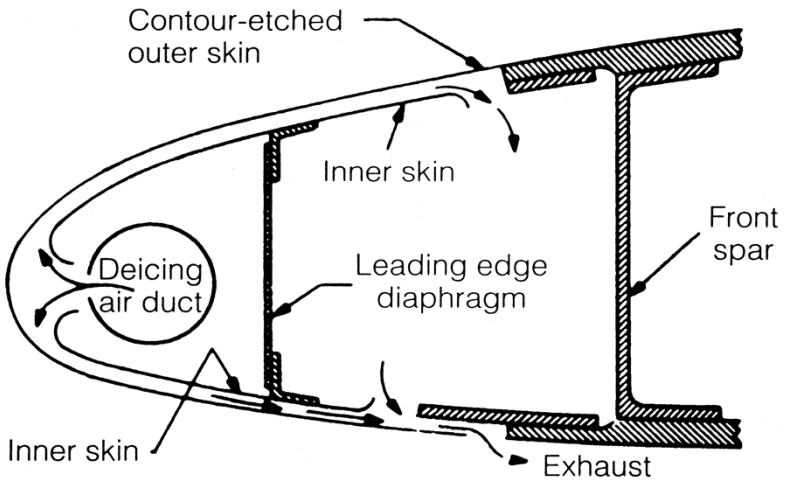
Anti-icing de-icing technologies

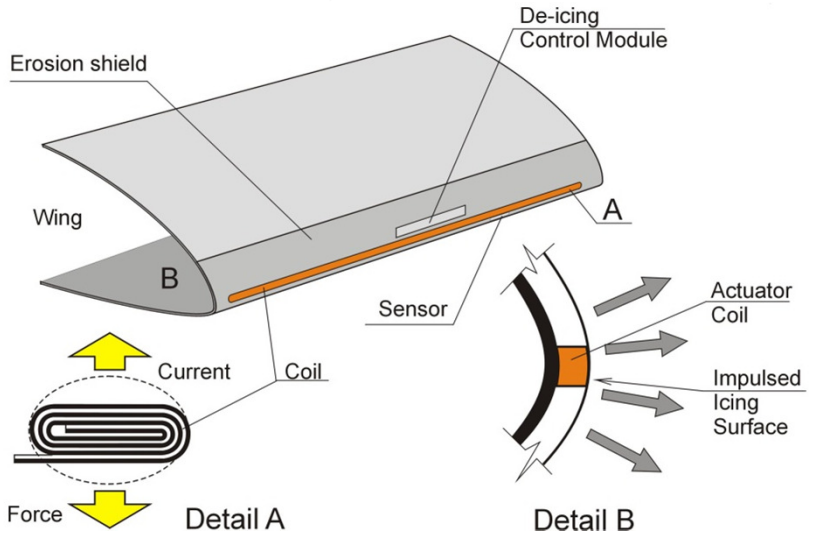


Active mode: chordwise underlay

SMA actuator activated by heating & deactivated expanding







Sensitivity to gust

One important feature of a UAV is its sensitivity to gust conditions. The lower the sensitivity, the better the design. Low sensitivity to gust can be achieved by high wing loading mg/S (high mg/S → lowh W/W_g → low $\Delta\alpha$ → low n → low sensitivity). It follows directly from the mathematical model expressed by equations (1-4).

$$\Delta\alpha = \frac{W_g - W}{V}, \tag{1}$$

$$m\dot{W} = \tfrac{1}{2}\rho V^2 S \frac{W_g - W}{V} C_{L\alpha}, \tag{2}$$

$$m\dot{W} + qS\frac{C_{L\alpha}}{V}W = qS\frac{C_{L\alpha}}{V}W_g, \tag{3}$$

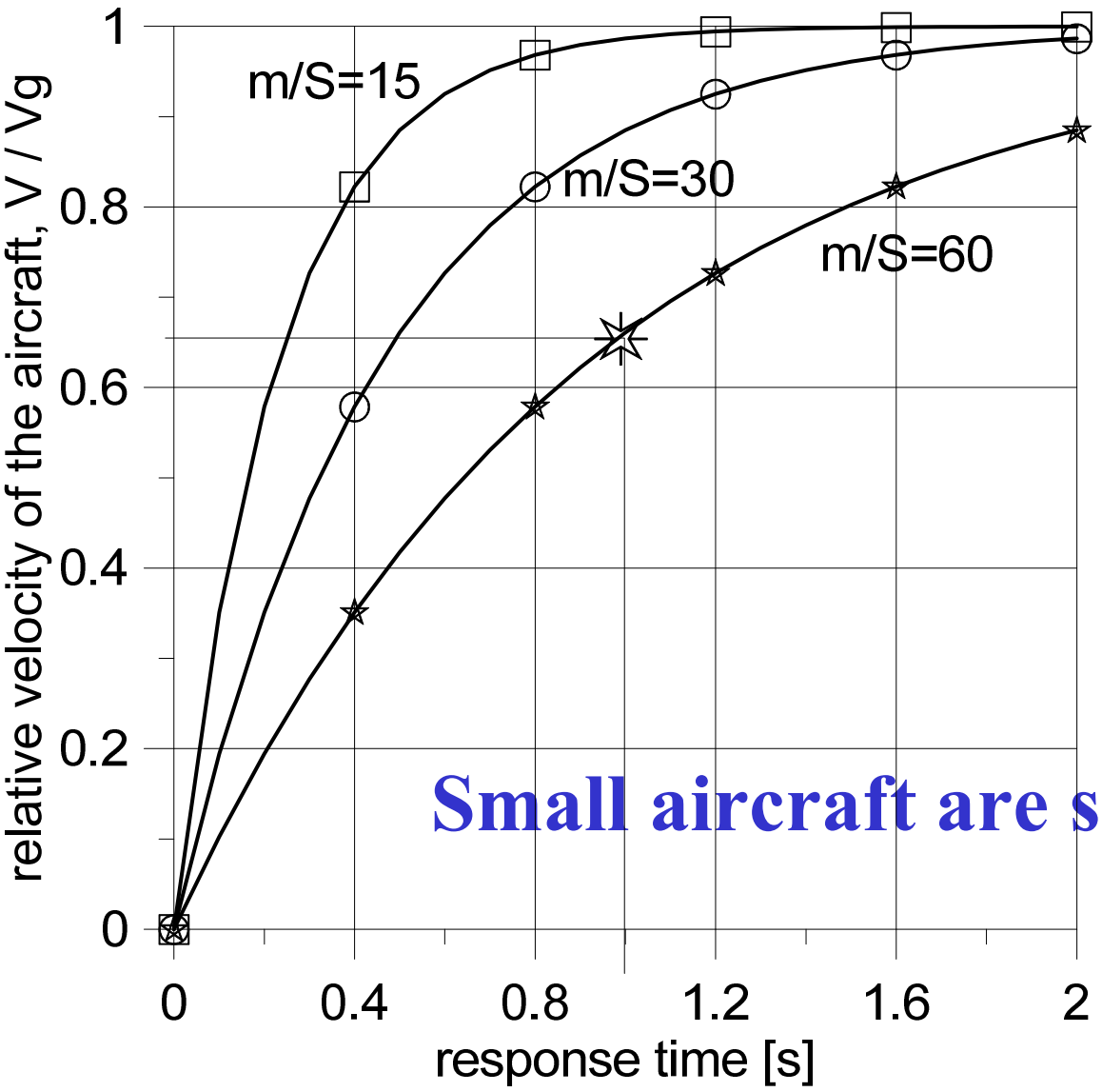
$$\frac{W}{W_g} = \left(1 - e^{-\frac{qSC_{L\alpha}}{mV}t}\right),. \tag{4}$$

because

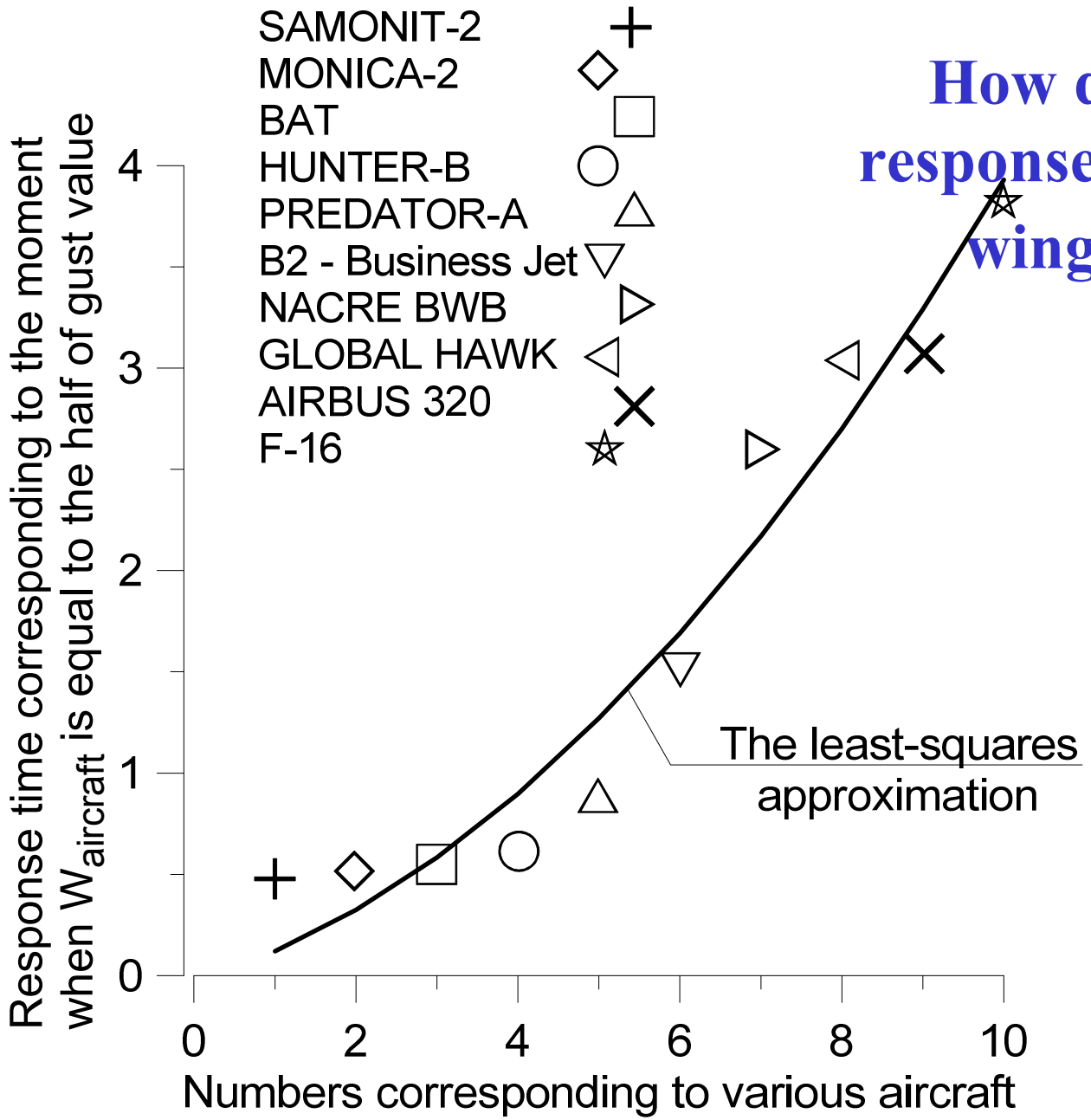
$$if\ \frac{mg}{S}\ is\ high\ then\ e^{F^*\frac{S}{mg}}\ is\ low\ and\ e^{-\frac{qSC_{L\alpha}}{mV}t} = \frac{1}{e^{\frac{qSC_{L\alpha}}{mV}t}} = \frac{1}{e^{F^*\frac{S}{mg}}}\ is\ high$$ and

$$\frac{W}{W_g} = \left(1 - e^{-\frac{qSC_{L\alpha}}{mV}t}\right)$$ is low and **$\Delta\alpha$ is low and load coefficient "n" is low.**

MONICA-2: response to vertical gust

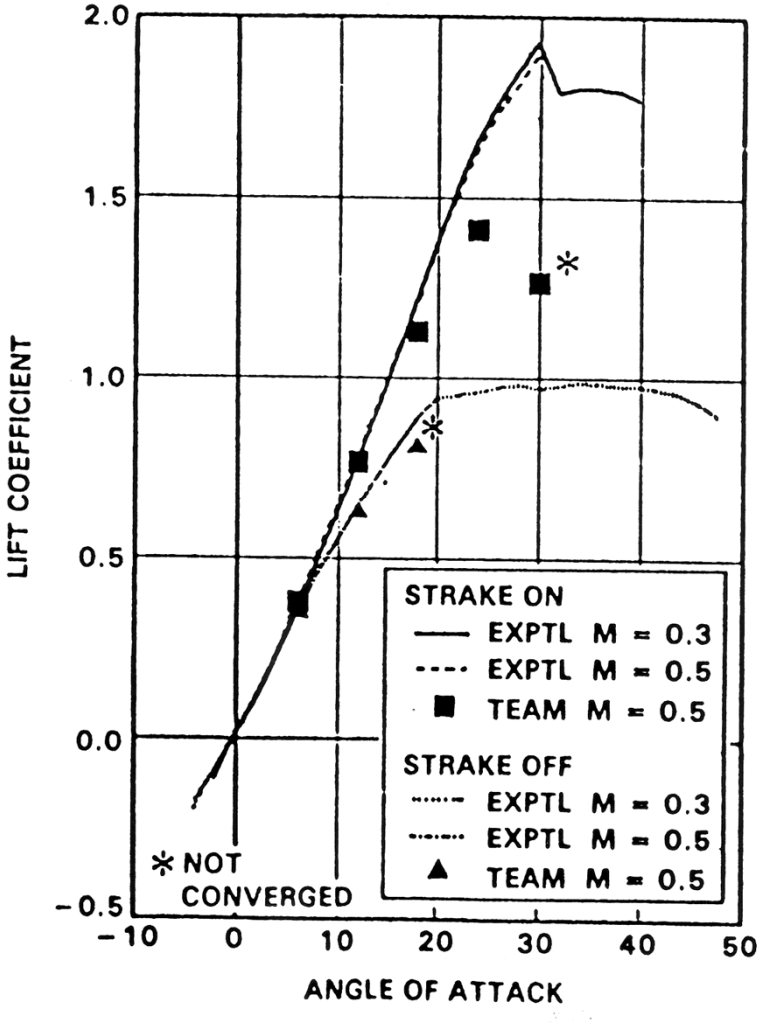


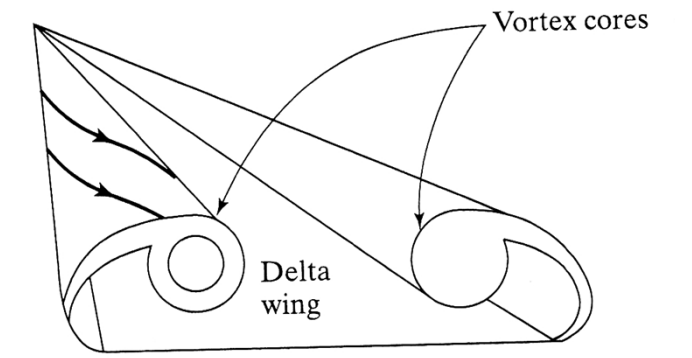
Small aircraft are sensitive to gust ...

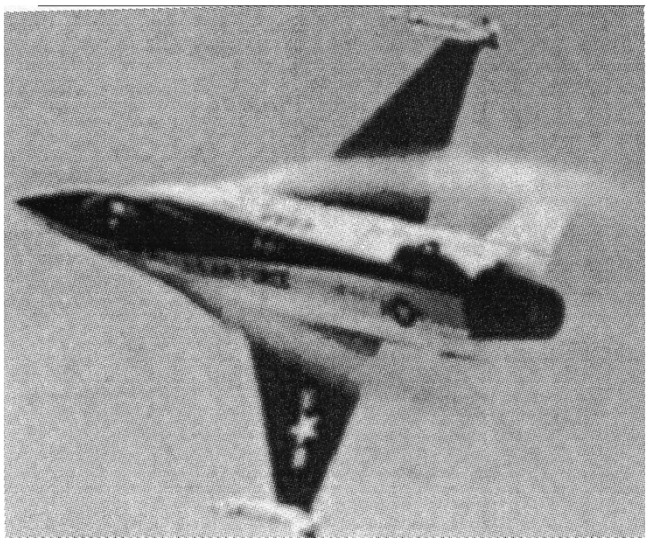


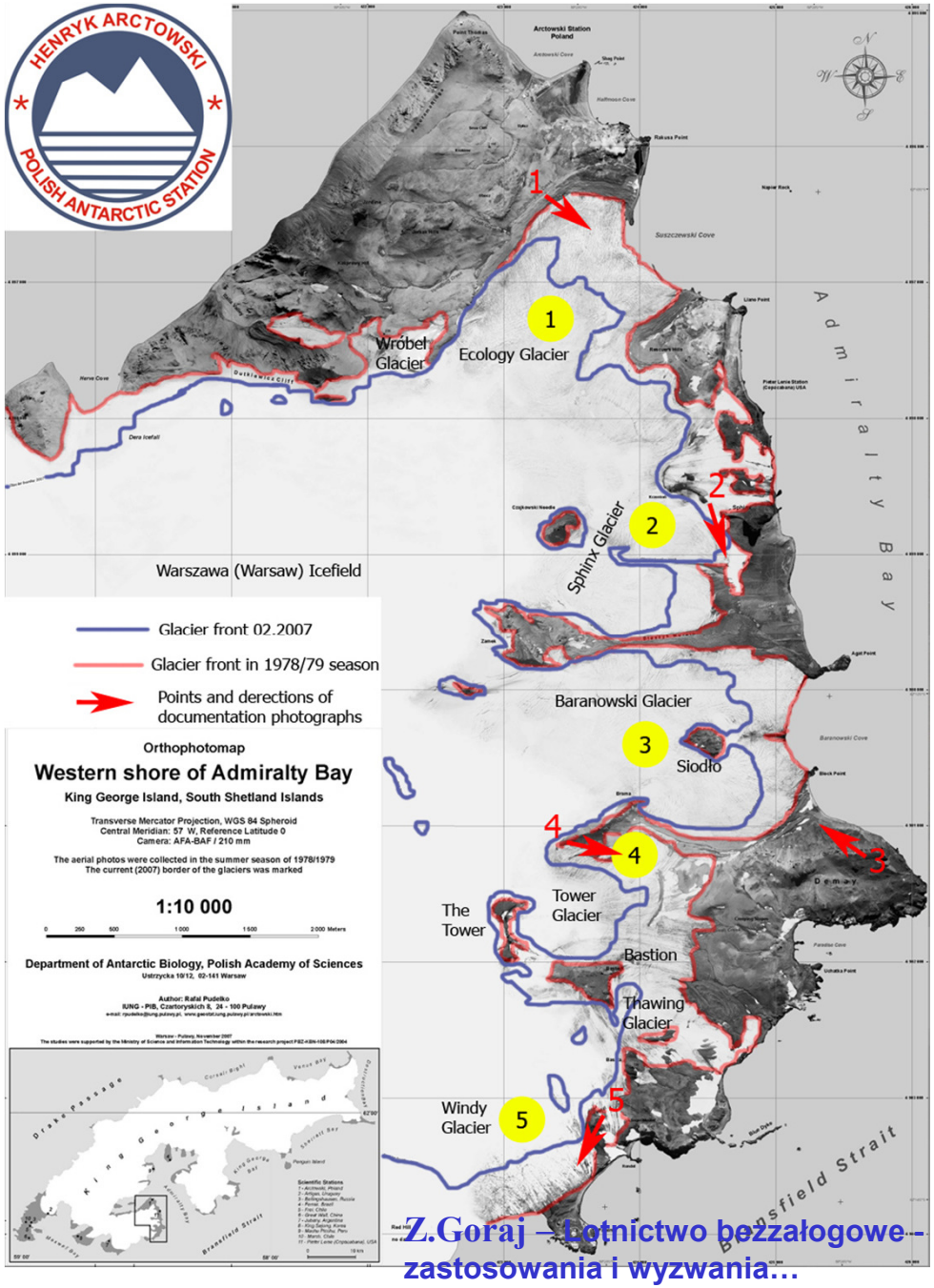
How does the gust response change versus wing loading …

What can we do to be more resistant to gust?









Glaciers on King George Island

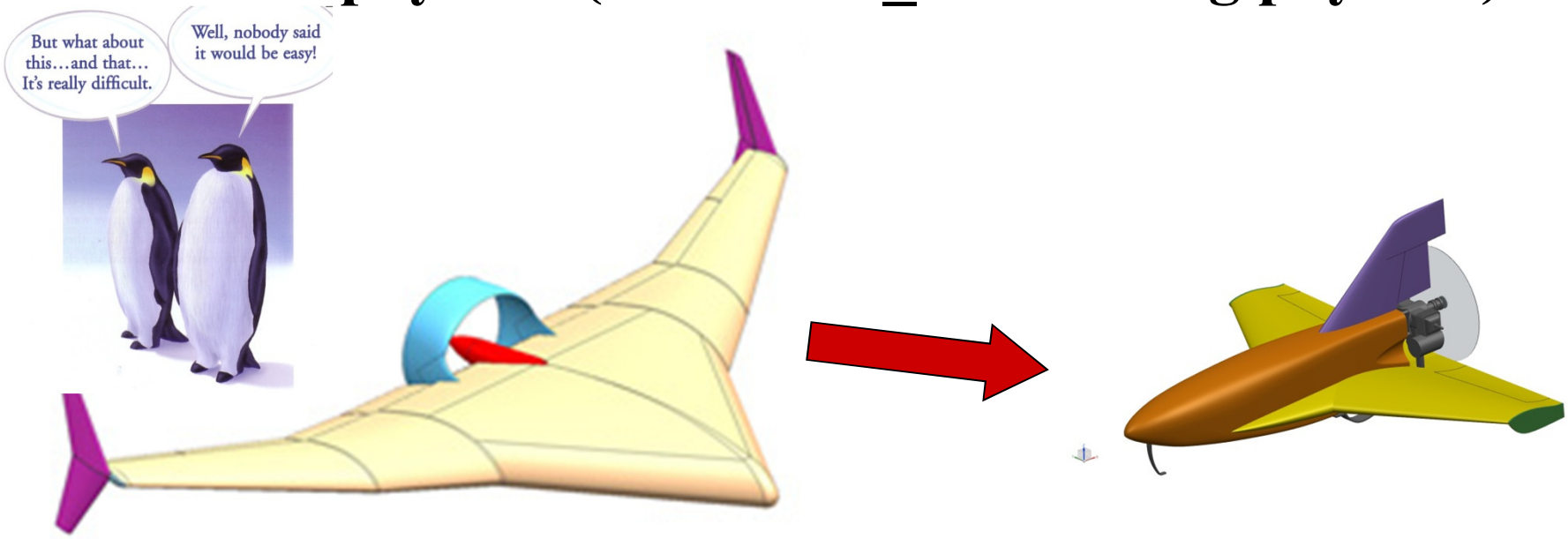
Norwegian research grant MONICA – „A novel Approach to monitoring the impact of climate change on Antarctic ecosystems" – Coordinator – Prof. Miroslaw Rodzewicz

Main goals:

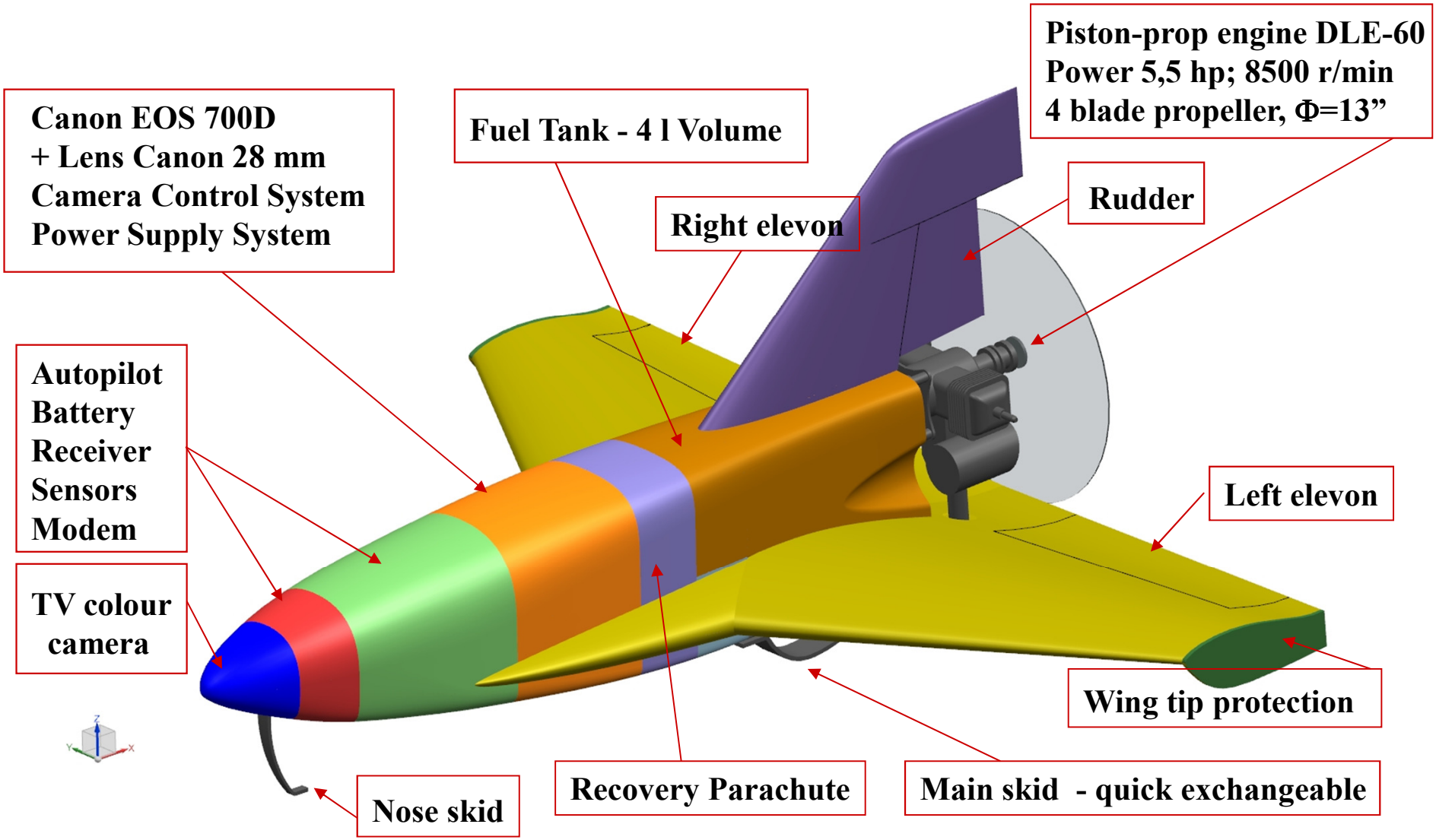
1. **To monitor and count penguins populations;**
1. **To prepare the so-called photo-orto-maps**

After Critical Design Review we have decided change the mind ... and cancel MONICA_1

1. **Too heavy aircraft, demanding a high energy catapult**
2. **There is no need to have 2 h endurance**
3. **Smaller payload (MONICA_1 had 10 kg payload)**

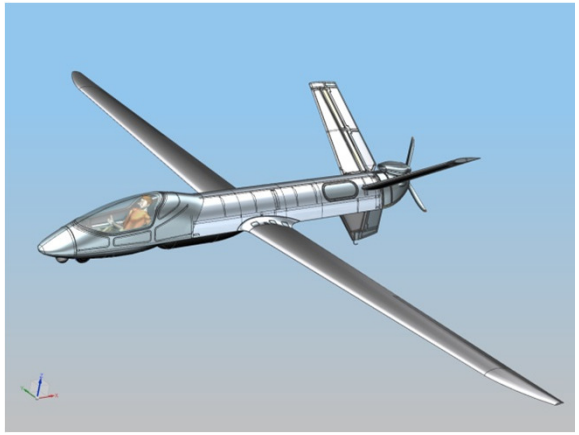


MONICA_2 – more classical & lighter version

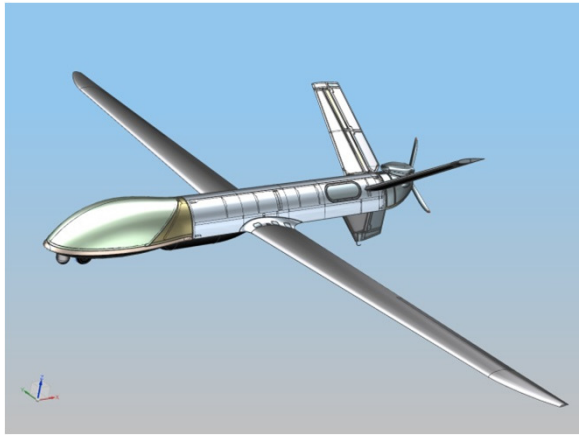


PW-100A – the first public presentation, Nov 19, 2016

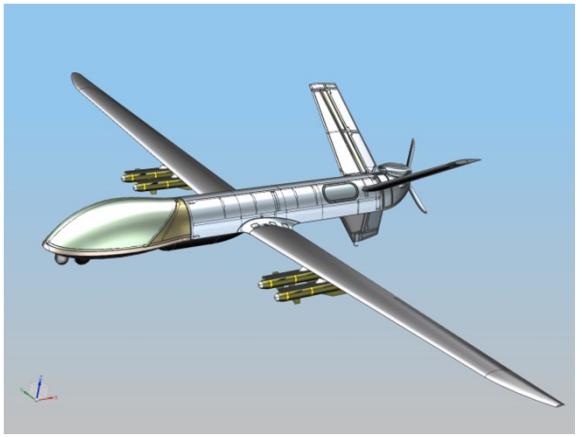
Phases of future development & main parameters



Phase I: manned version, MTOW=600 kg



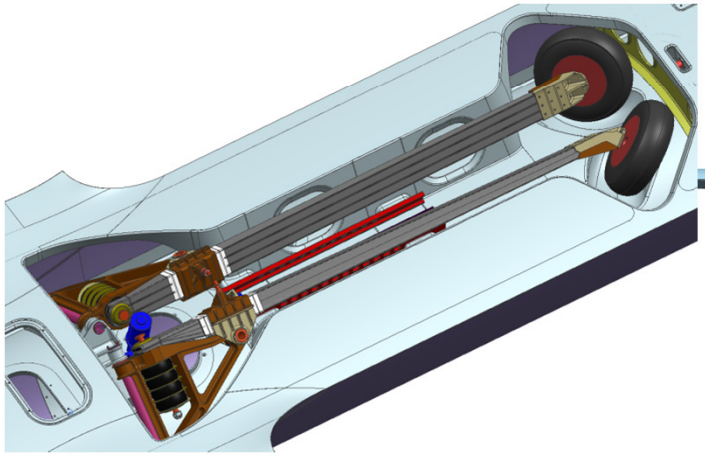
Phase II: unmanned version, MTOW=600 kg

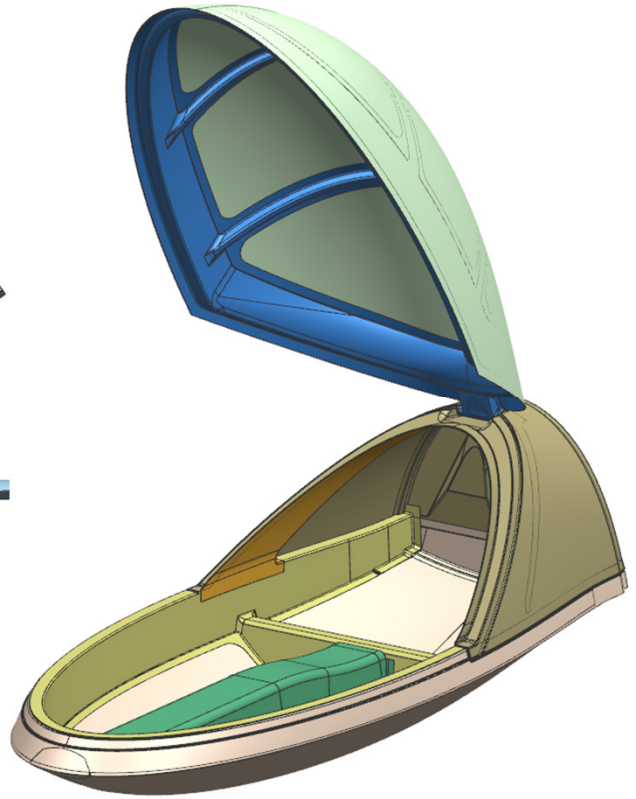


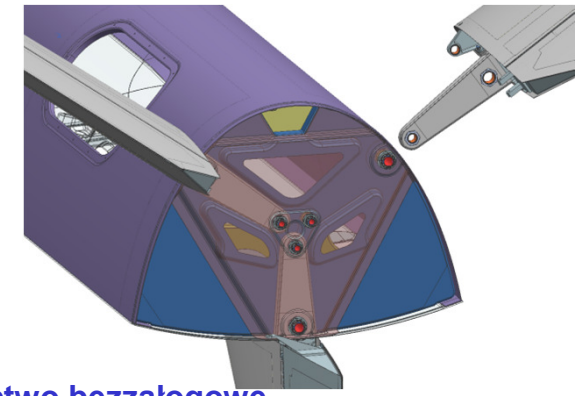
Phase III: unmanned version, MTOW=1200 kg

Parameters	PW-100C	MQ-1 Predator	Hermes 900
Wing span	15 m	17 m	15 m
Take-off weight	1100 kg	1043 kg	1100 kg
Power unit	Rotax 912 iS	Rotax 940 turbo	Rotax 914
Fuel mass	660 kg	286 kg	300 kg
Payload	300 kg	300 kg	300 kg
Endurance	75 h	40 h	36 h
Max flight speed.	230 km/h	250 km/h	222 km/h
Loiter speed	110 km/h	120 km/h	111 km/h
Max flight altitude	9000 m	8000 m	10000 m

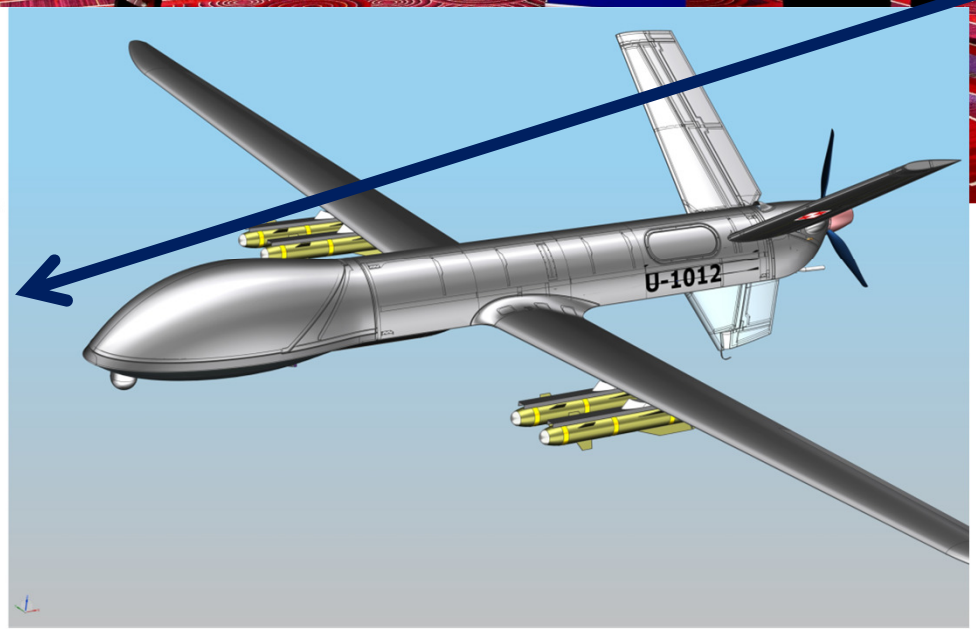
Modular concept & design





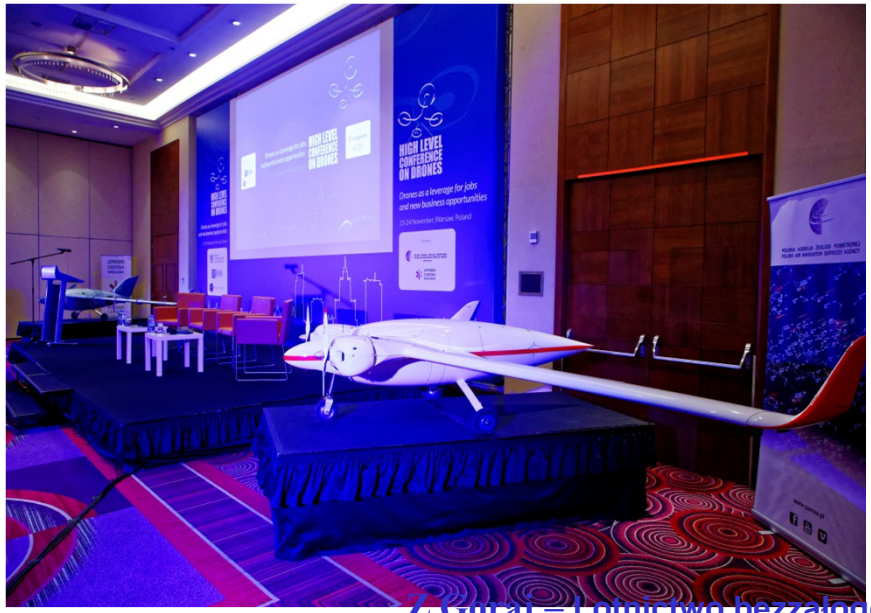


High Level Conference on drones, Warsaw, Nov 23-24, 2016



High Level Conference on drones, Warsaw, Nov 23-24, 2016

Mrs Violeta Bulc, European Commissioner for Mobility and Transport opened the Conference



Photos: **Andrzej Mroczek**

PW-100A – what next?

A. Systemy absolutnie niezbędne do lotu bezzałogowego:

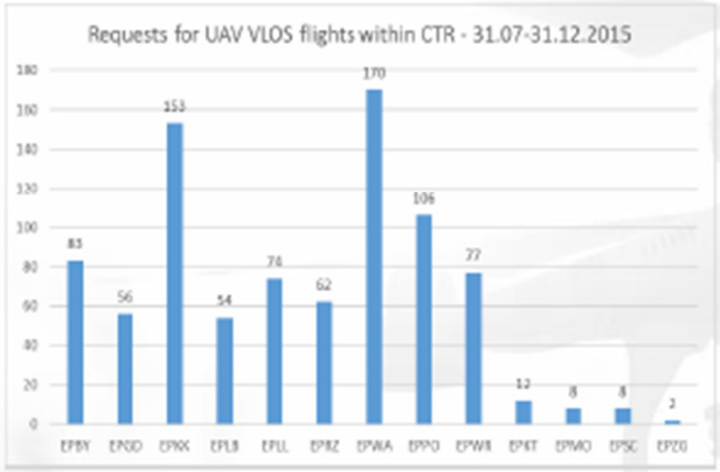
1. System sterowania fly-by-wire lub fly-by-light;
2. System łączności bezpośredniej (line-of-sight) wraz z systemem anten, wyborem częstotliwości, stacją kontroli naziemnej (na bazie samochodu – duży van lub ciężarowy) oraz systemem link-down, link-up;
3. System nawigacji oparty o hybrydowy GPS-INS;
4. System automatycznego startu i lądowania ATOL;
5. System rozpoznawania przeszkód, tzw. „See and Avoid”;

Realizacja lotów testowych:

Załogowy; → bezzałogowy z tzw. “pilotem bezpieczeństwa”
→ w pełni bezzałogowy w systemie fly-by-wire

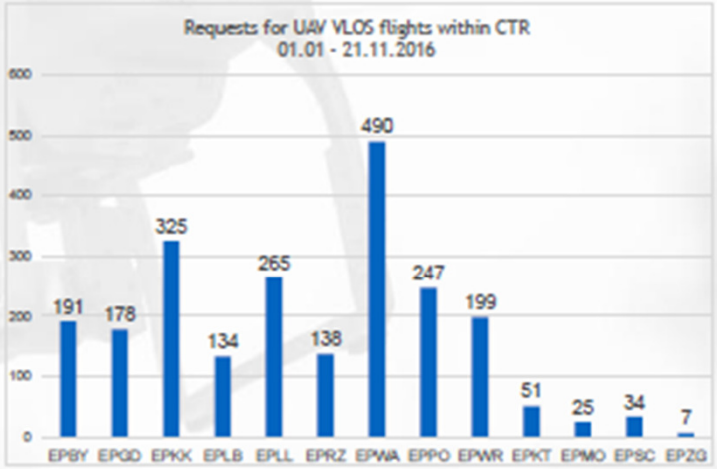
Sytuacja w Polsce, Polska Agencja Żeglugi Powietrznej

Requests for UAV VLOS flights within controlled airspace (CTR)



865 flights in 5 months
2015
173 flights/month

2311 flights in 11 months
2016
210 flights/month



POLSKA AGENCJA ŻEGLUGI POWIETRZNEJ
POLISH AIR NAVIGATION SERVICES AGENCY

Drony w PKP - CARGO

Lokalizowanie zdarzeń i trudności eksploatacyjnych

Monitorowanie przejazdu pociągów

Monitorowanie szlaków kolejowych

5. Przykłady na wykorzystanie dronów w PKP CARGO S.A.

Sektory Cywilnego Rynku Dronów

Wyzwania na przyszłość w zastosowaniach cywilnych