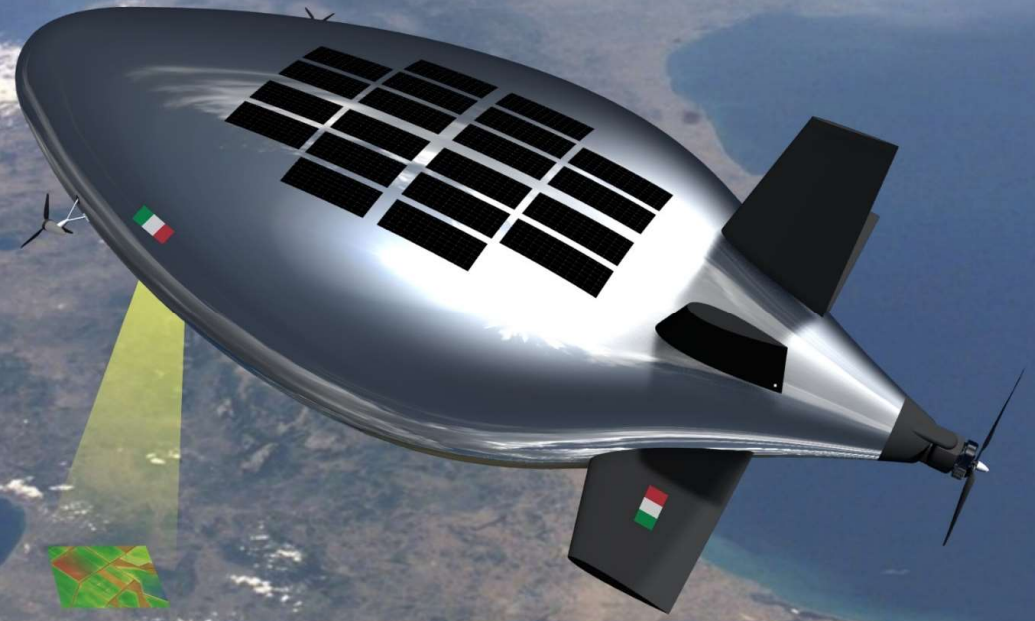
Piattaforme Stratosferiche:

una nuova frontiera tecnologica e applicativa per i Sistemi Unmanned

26 | 01 | 2024



Vincenzo Rosario Baraniello

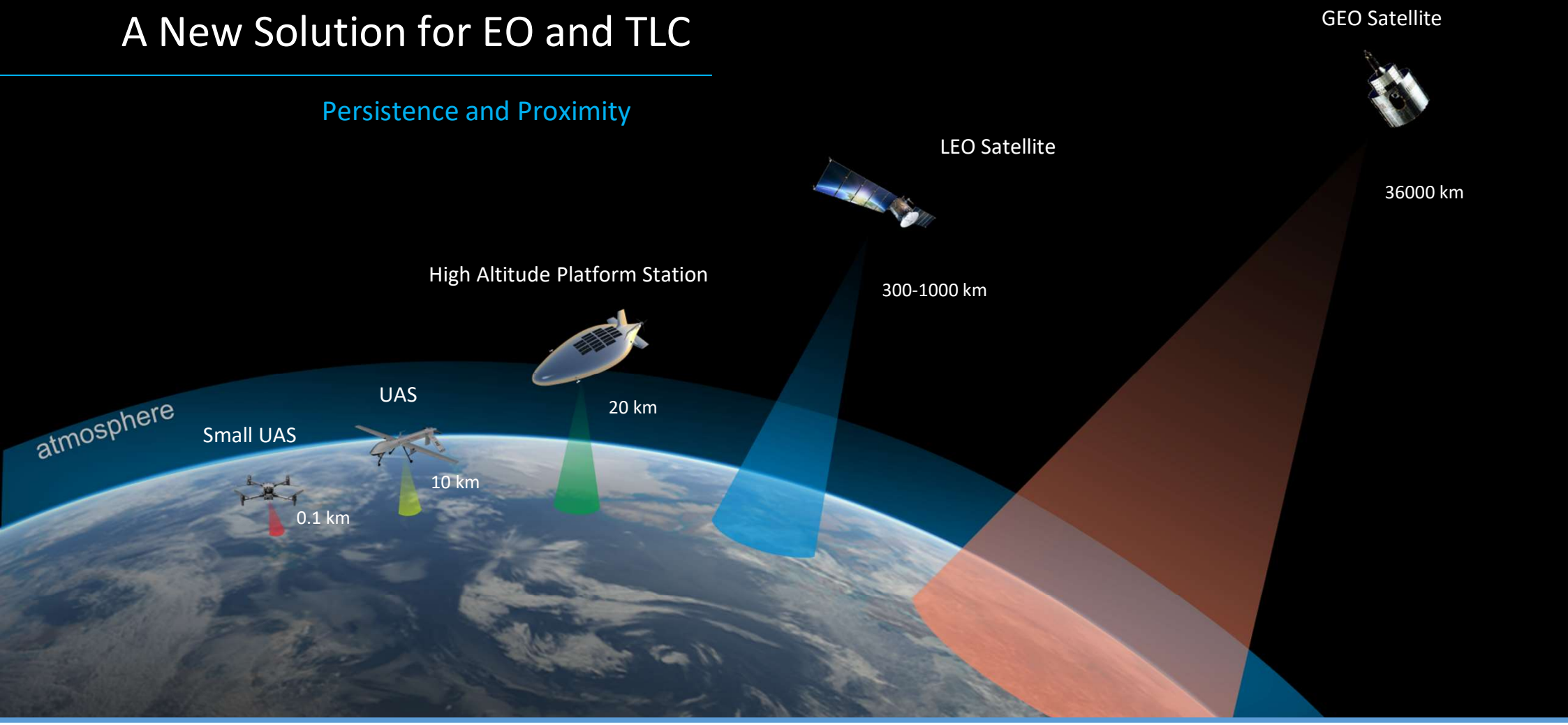
Responsabile Laboratorio Piattaforme Stratosferiche

CIRA–Italian Aerospace Research Centre

CIRA
Centro Italiano Ricerche Aerospaziali

A New Solution for EO and TLC

Persistence and Proximity



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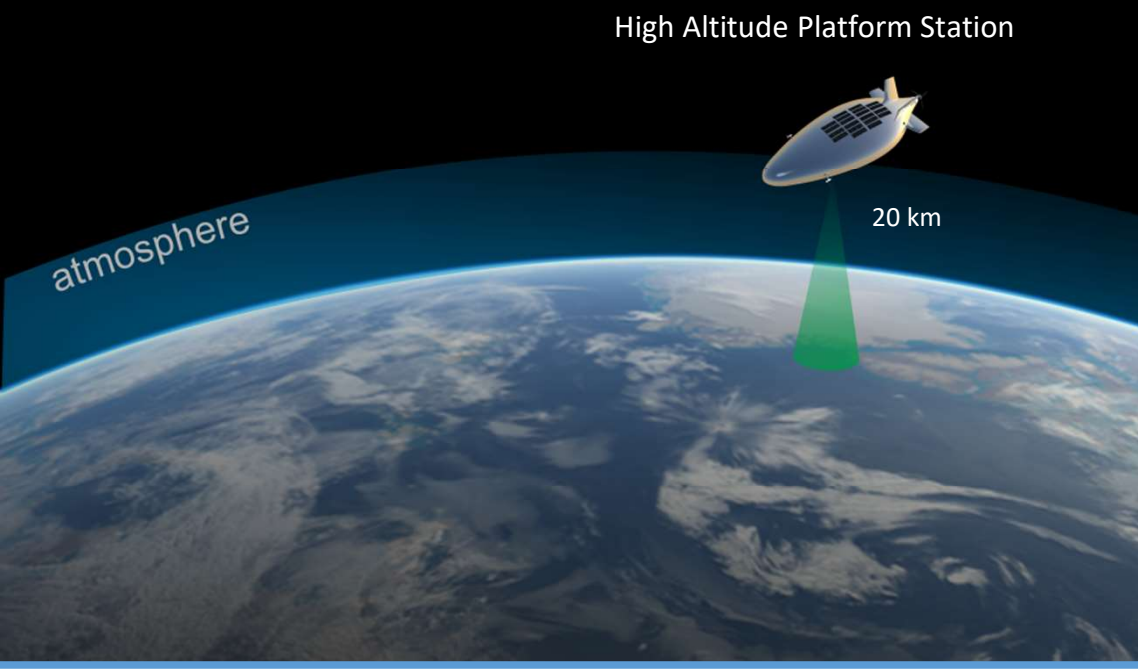
Persistence and Proximity



New Earth Observation Applications needs platforms that can stay on target for long time | day | week | month.
They need Persistence

New Earth Observation Applications needs platforms that can have very high spatial and spectral resolution on the target. They need Proximity

New Telecommunication Applications needs platforms that can stay over the users for long time | day | week | month. They need Persistence

New Telecommunication Applications needs low latency that is directly related to the distance to the users.
They need Proximity

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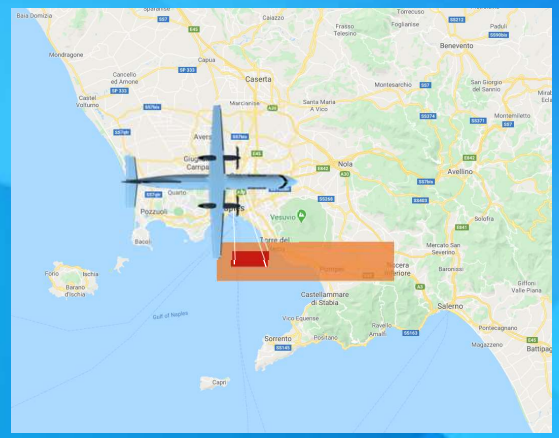
Satellite Monitoring

Global Scale

HAPS Monitoring

Regional Scale

Aircraft Monitoring



Local Scale

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	Satellite Monitoring Global Scale	HAPS Monitoring Regional Scale

Revisit Time	• WorldView-3:
	  • 1 day nadir
	  • 4.5 days off nadir < 20°
	• Sentinel-2
	  • 10 days or 5 days combining constellation
		• In station-keeping mode: Persistent
		
		• In mapping mode (on regional area like Campania): Within 48 hours

Swath	• WorldView-3: 13.1km • Sentinel-2: 290km	Up to 20x15km

Resolution	• WorldView-3:
	  • 0.31m (pan)
	  • 1.24m (bands)
	• Prisma:
	  • 30m (hyperspectral)
		• Visible: up to 0.30cm (bands)
		• Multispectral: up to 0.50m
		• Hyperspectral: up to 0.70m
		• Fluorescence: up to 0.8m
		• Thermal LWIR: up to 1.2 m

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150-250 kg MTOW

20-60 kg Payload

Persistency & Proximity

Altitude of 18 km

Endurance > 4 month

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Stratospheric Platforms: A Historical Perspective (1/3)

Teledyne-Ryan AQM-91A Compass Arrow ~1971

TECHNICAL NOTES:
Operational altitude: 78,000 ft.
Endurance: 4.5 hours
Range: 2,000 miles
Photography: Coverage of an area 1,720 miles long and 43 miles wide
Span: 48 ft.
Length: 34 ft.
Weight: 5,245 lbs.

Boeing Condor ~1988

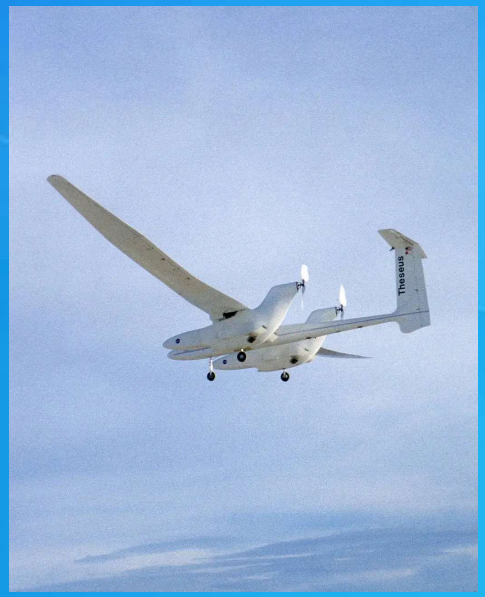
First aircraft to fly a fully automated flight from take-off to landing in 1988.
It set the world piston-powered aircraft altitude record of 20,430 m.
Record of endurance: 50 hours

Span: 205 ft.
Length: 66 ft.
Weight: 21,000 lbs.

Stratospheric Platforms: A Historical Perspective (2/3)

Aurora Perseus~ 1994

TECHNICAL NOTES:
Operational altitude: 18,000 m
Endurance: 24 hours



Aurora Theseus~ 1996

TECHNICAL NOTES:
Operational altitude: 18,000 m
Endurance: 50 hours

AeroVironment Pathfinder~ 1993

AeroVironment Centurion~ 1998

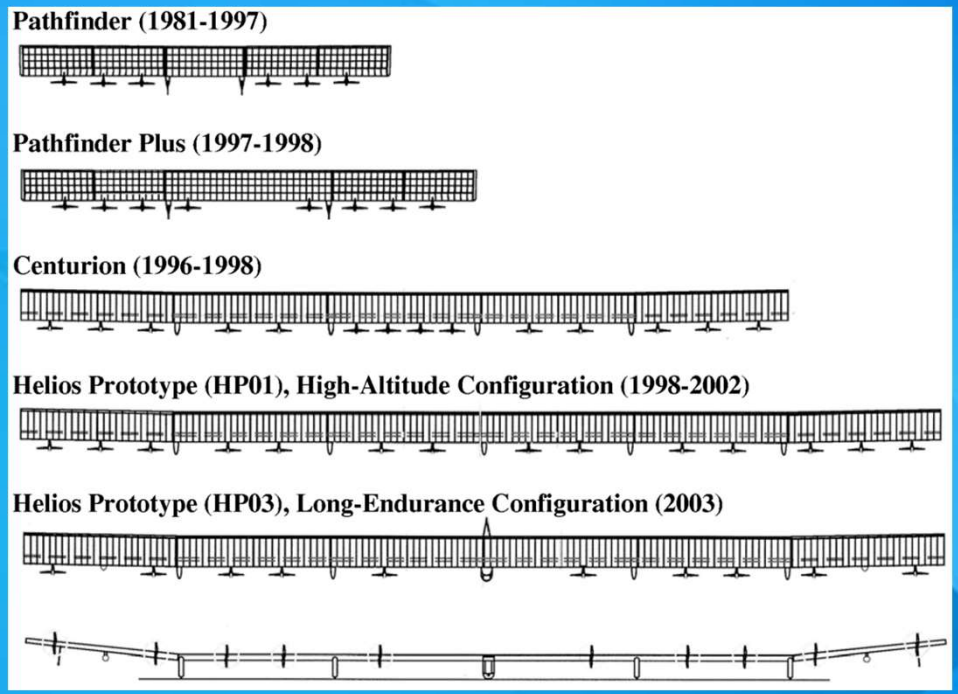
AeroVironment Helios~ 2000

NASA ERAST Program - ERAST was a multiyear effort to develop the aeronautical and sensor technologies for a new family of remotely piloted aircraft intended for upper atmospheric science missions

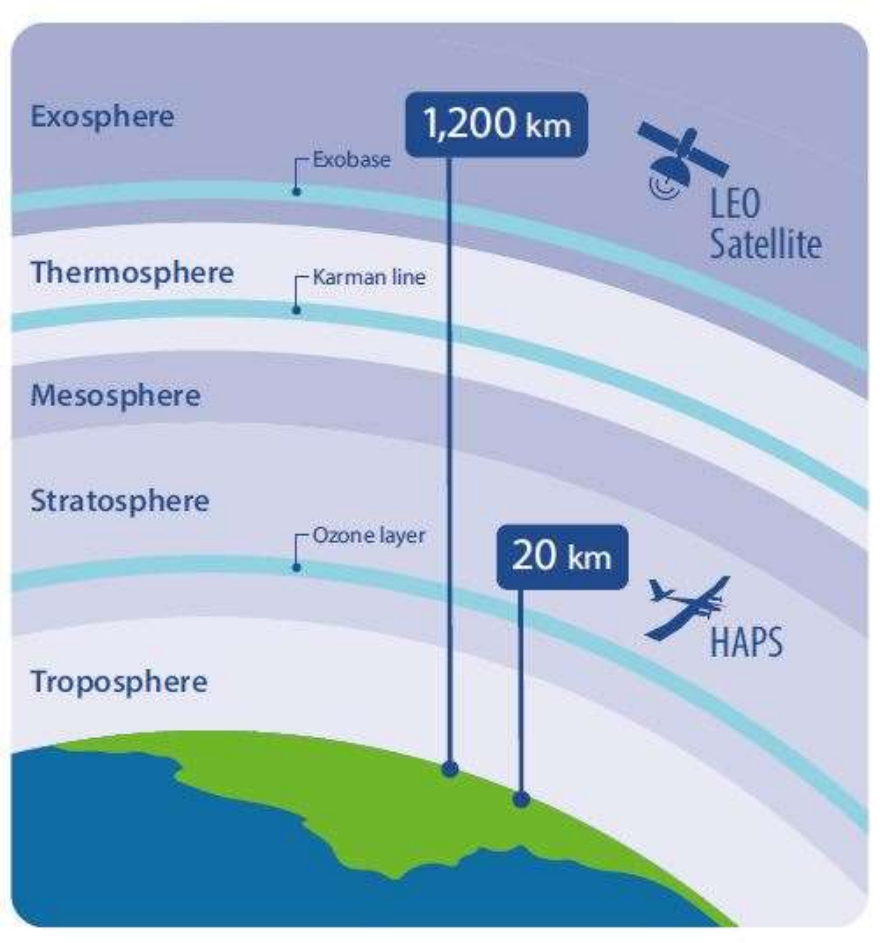
Stratospheric Platforms: A Historical Perspective (3/3)

Specifications[1][3][6][7]

	Pathfinder	Pathfinder-Plus	Centurion	Helios HP01	Helios HP03
Length ft (m)	12 (3.6)	12 (3.6)	12 (3.6)	12 (3.6)	16.5 (5.0)
Chord ft (m)	8 (2.4)				
Wingspan ft (m)	98.4 (29.5)	121 (36.3)	206 (61.8)	247 (75.3)	
Aspect ratio	12 to 1	15 to 1	26 to 1	30.9 to 1	
Glide ratio	18 to 1	21 to 1	?	?	?
Airspeed kts (km/h)			15–18 (27–33)	16.5–23.5 (30.6–43.5)	?
Max altitude ft (m)	71,530 (21,802)	80,201 (24,445)	n/a	96,863 (29,523)	65,000 (19,812)
Empty Wt lb (kg)	?	?	?	1,322 (600)	?
Max. weight lb (kg)	560 (252)	700 (315)	1,900 (862)	2,048 (929)	2,320 (1,052)
Payload lb (kg)	100 (45)	150 (67,5)	100–600 (45–270)	726 (329)	?
Engines	electric, 2 hp (1.5 kW) each				
No. of engines	6	8	14	14	10
Solar pwr output (kW)	7.5	12.5	31	?	18.5
Supplemental power	batteries	batteries	batteries	Li batteries	Li batteries, fuel cell



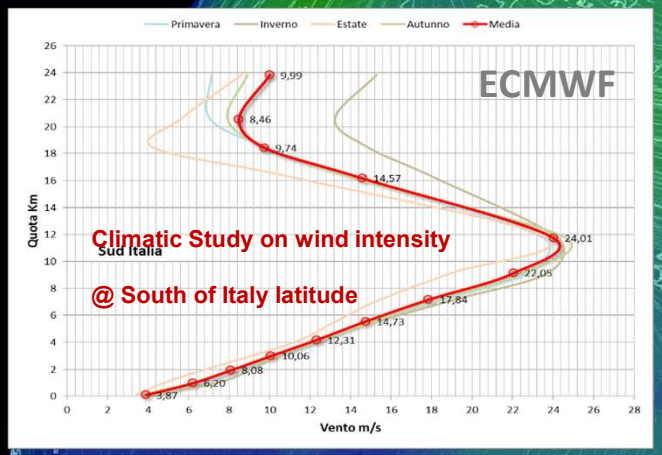
NASA ERAST Program - ERAST was a multiyear effort to develop the aeronautical and sensor technologies for a new family of remotely piloted aircraft intended for upper atmospheric science missions

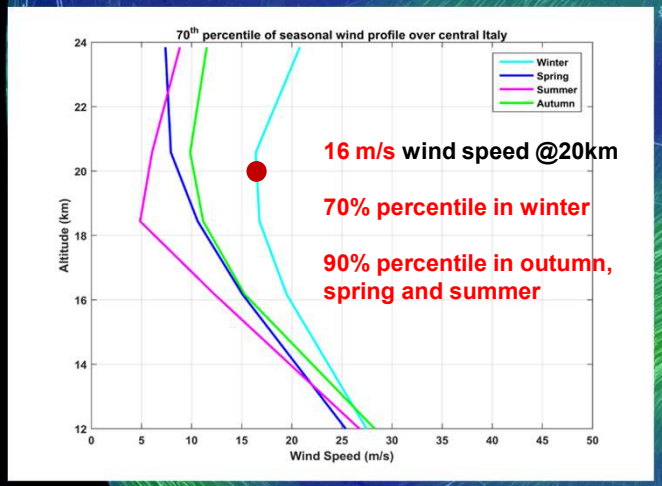


Stratosphere a Complex Environment

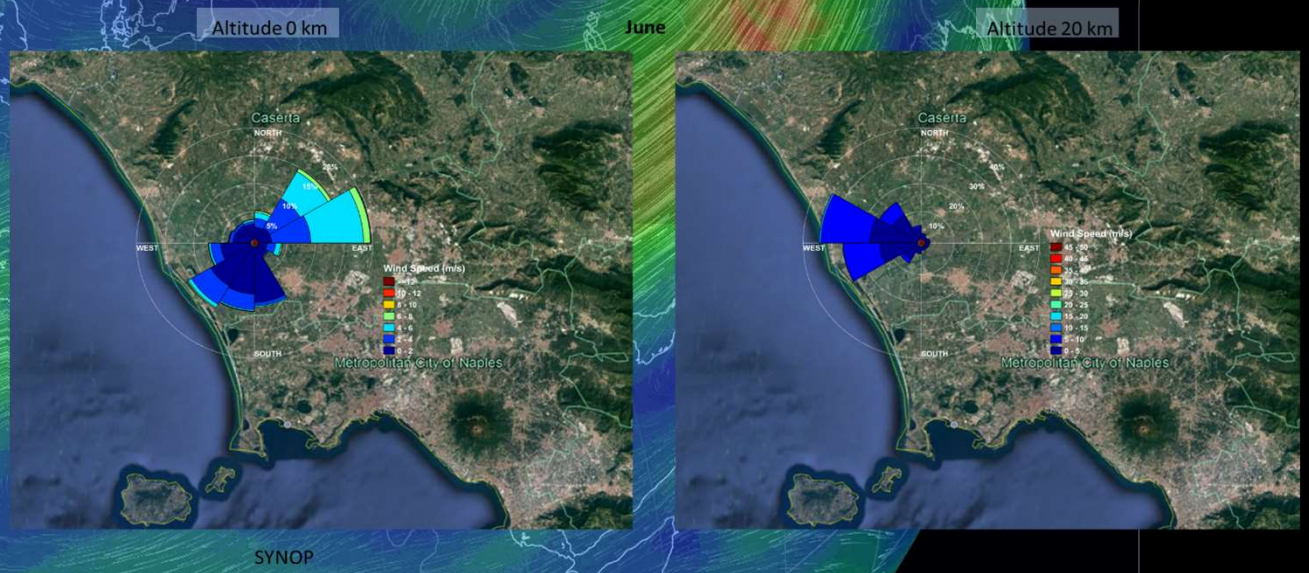
- **Air Density only 10% respect Sea Level**
- **Temperature -70°**
- **First interaction of Ionizing radiation with atmosphere**
- **UV Radiation**
- **Ecc..**

Study on Operative Environment





The period considered for the analysis is 1987-2016, ie the last 30 years available for the ERA-Interim dataset. The analysis of a time period of at least 30 years is recommended by the WMO (World Meterological Organization) for a correct climatic characterization.



earth

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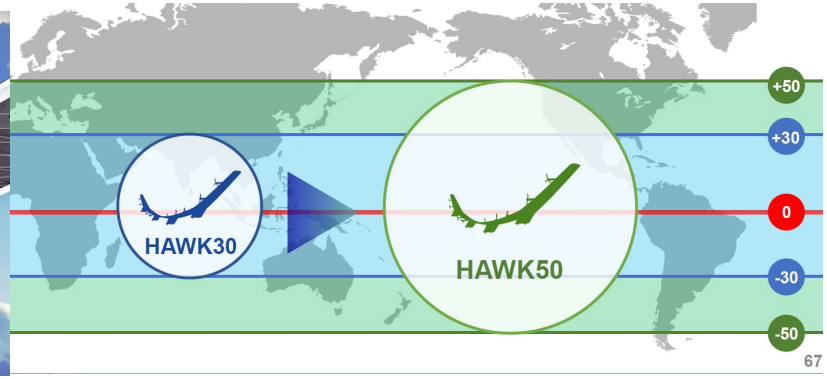
State of the Art HTA

TLC : A 'super cell tower' in the stratosphere: AeroVironment and SoftBank's 5G vision

SoftBank

Invest 126 M dollar in HAPS Development

Aerovironment as supplier



State of the Art LTA

State of the Art

China's first near-space solar-powered large unmanned aerial vehicle completed its maiden flight. Called Qimingxing-50 (Morning Star), it can double up as a satellite and can be used for time-sensitive operations and during war

FP Explainers | September 08, 2022 18:00:32 IST

The drone can operate in near-space, 20 km above the Earth's surface. This makes it capable of carrying out functions of a satellite. Image courtesy: @liupheonix/Twitter

In a big step toward green development, China has built its first solar-powered large unmanned aerial vehicle. The drone successfully carried out its maiden flight on Saturday. It took off from an airport in Yulin, northwest China's Shaanxi province and landed smoothly after 26 minutes airborne with all systems operating normally, according to a report in state-run *Global Times*.

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February 3, 2023 Suspected Chinese spy balloon flies over the US

By Aditi Sangal, Leinz Vales, Adrienne Vogt, Matt Meyer, Elise Hammond and Tori B. Powell, CNN

Updated 0532 GMT (1332 HKT) February 4, 2023

See how the suspected Chinese spy balloon may have made its way to the US 02:08

Sameer Joshi
@joe_sameer · Follow

21+ hours in the Air - NewSpace Research and Technologies #NRT creates a #National #UAV #Endurance #Record #Benchmark in India

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5:18 AM · Dec 23, 2023

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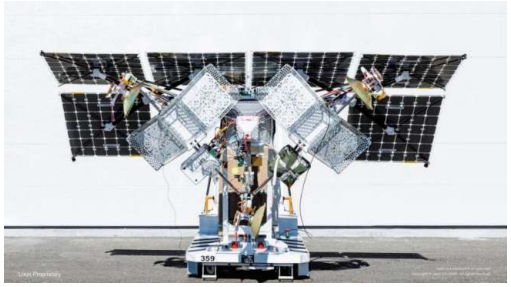
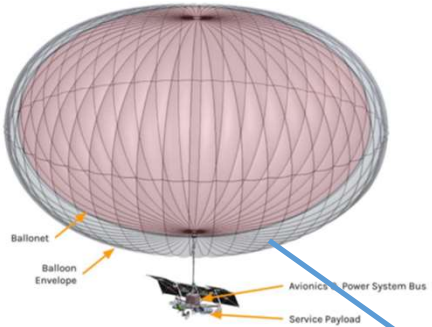
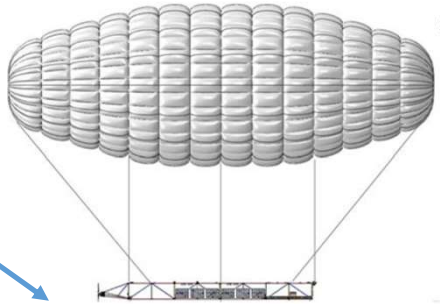
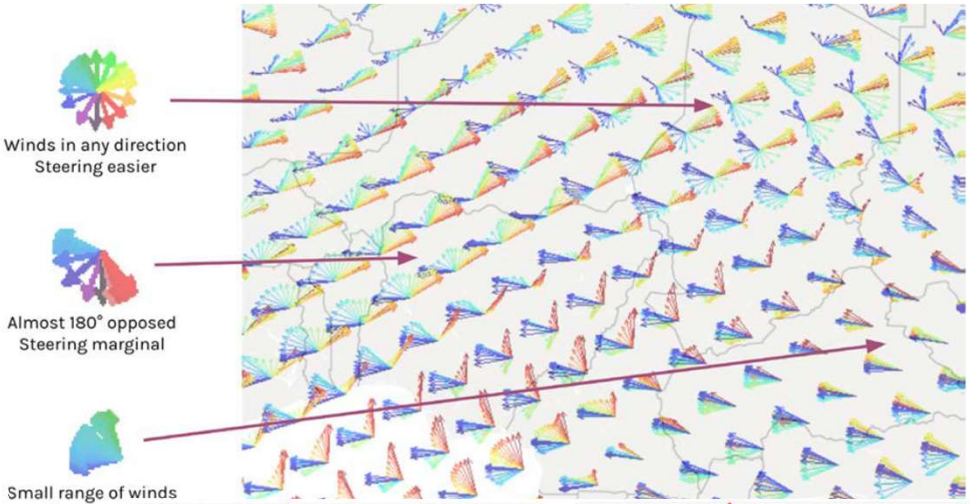
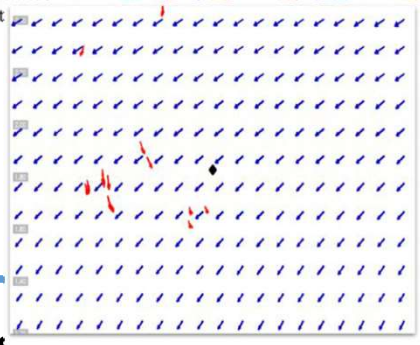
Alphabet shutting down LOON

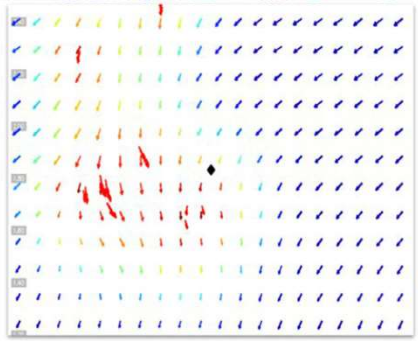












Some Results

14 Jul 2023

British engineers have successfully completed a stratospheric flight trial of BAE Systems' High Altitude Pseudo Satellite (HAPS) Uncrewed Aerial System (UAS) - PHASA-35.

Over a 24-hour period, PHASA-35 soared to more than 66,000 feet, reaching the stratosphere, before landing successfully. The trial, completed last month in New Mexico in the USA, allowed engineers to assess the performance of the experimental solar-electric drone within the outer-reaches of the planet's atmosphere.

The flight marks a significant milestone in PHASA-35's development which began in 2018. Designed by BAE Systems' subsidiary Prismatic Ltd to operate above the weather and conventional air traffic, it has the potential to provide a persistent and stable platform for various uses including ultra-long endurance intelligence, surveillance and reconnaissance, as well as security.

CNET

Tech Money Home Wellness Home Internet E

Tech > Mobile

Project Loon has been in the sky for 1 million hours

Alphabet's remote connectivity hot air balloons have flown 40 million kilometers.

Corinne Reichert
July 23, 2019 5:06 p.m. PT

So close! Zephyr drone lands just hours before setting flight-duration record

News By Brett Tingley published August 30, 2022

The Airbus Zephyr S came down on Friday (Aug. 19) after remaining in the air for over 64 days and setting a number of records.

Flight crews help the Zephyr drone take off. (Image credit: Airbus/Christian Otto)

An experimental high-altitude drone being tested in conjunction with the United States Army has ended its epic flight just hours before breaking the world record for longest flight duration.

The Airbus Zephyr S came down on Friday (Aug. 19) after remaining in the air for over 64 days and setting a number of records, including longest continuous flight of an uncrewed aircraft at 64 days, 18 hours, 26 minutes.

Some Results

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SoftBank Corp. successfully completes flight test of sub-scale model of nexgen HAPS UAS

AUGUST 9, 2023

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Sceye completes third test flight for high altitude communications airship

Another HAPS player gets closer to deployment

August 21, 2023 By: Georgia Butler Comment

US-based High altitude pseudo satellite (HAPS) startup Sceye has successfully completed its third test flight in three months.

The company shared on LinkedIn that on Wednesday, August 16, the third stratospheric flight test of its airship platform completed "all primary objectives, including attitude and automated pressure control, beyond-line-of-sight command, and reliable launch and ascent."

– Sceye

The test flight also successfully enabled three independent and redundant data links, and also carried multiple payloads including an infrasonic

"On the capabilities and limitations of high altitude pseudo-satellites"
Gonzalo et alt. 2018 Elsevier | Progress in Aerospace Science

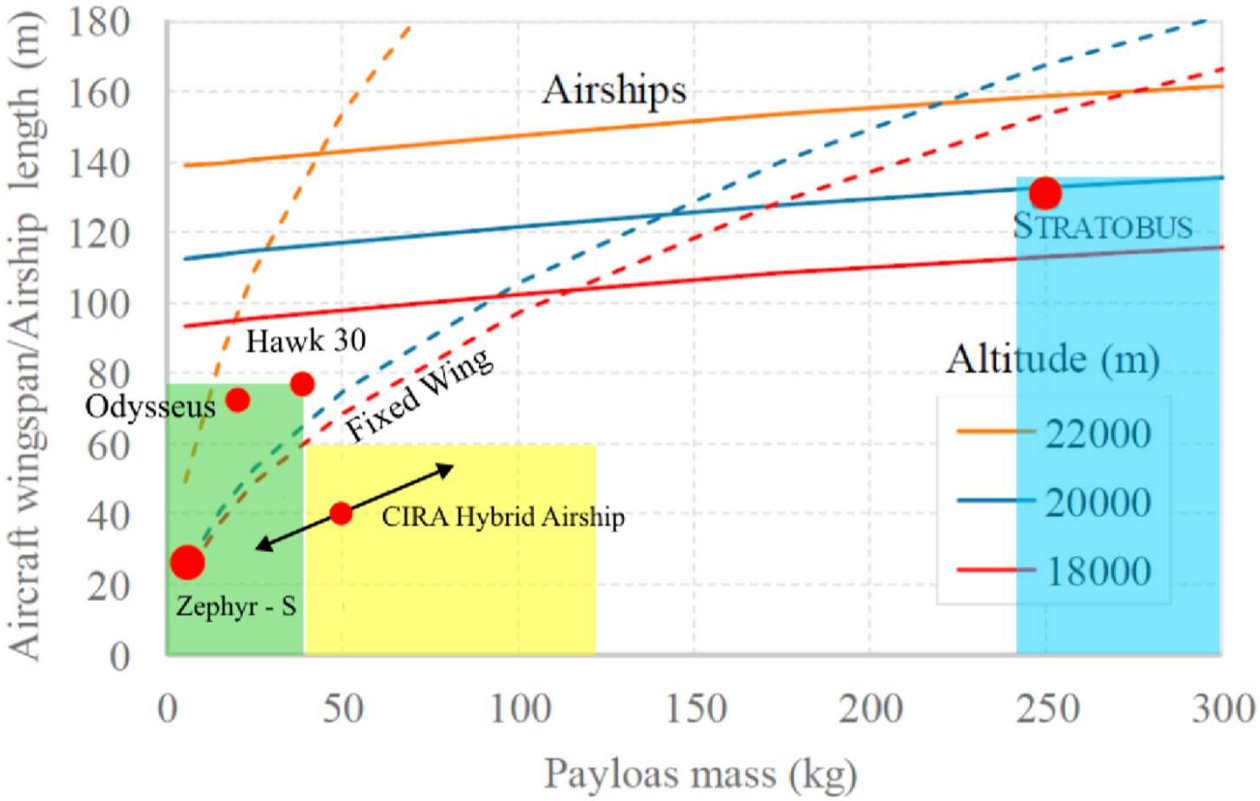
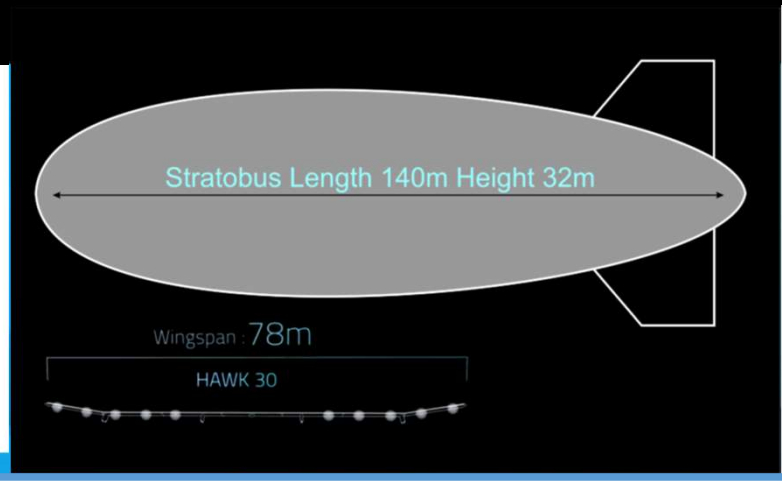
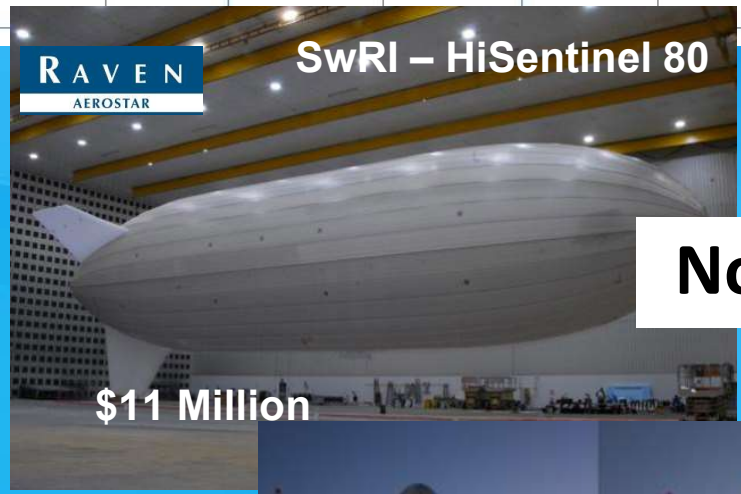


Fig. 19. Aircraft size required for different payloads and flight levels (dashed lines: airplanes; solid lines: airships).



Nome	Azienda	Tipologia	Quota	Endurance	Volume	Lunghezza	P/L weight (kg)	Platform Weight (kg)	Rapporto peso P/L /peso piattaforma
HiSentinel 80	SwRI	**HALE**	20 km	Flight 8 hrs/6 hrs float	6800 m3	60 m	**36**	**500**	**7,20%**
HALE-D	Lockheed Martin	**HALE**	18 km	5 days	14158 m3	73 m	**36**	**1361**	**2,65%**



No Ballonet

Ballonet
Vs
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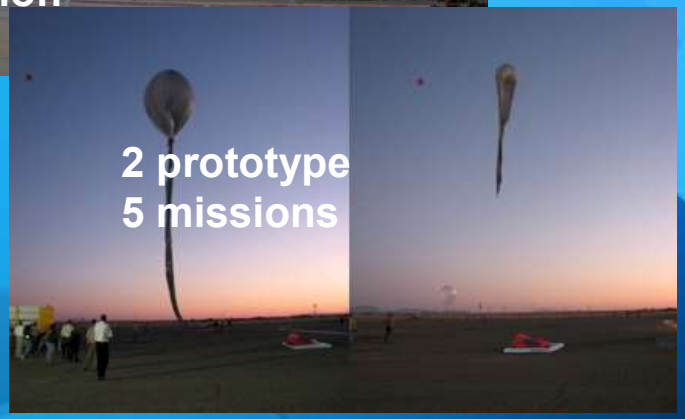
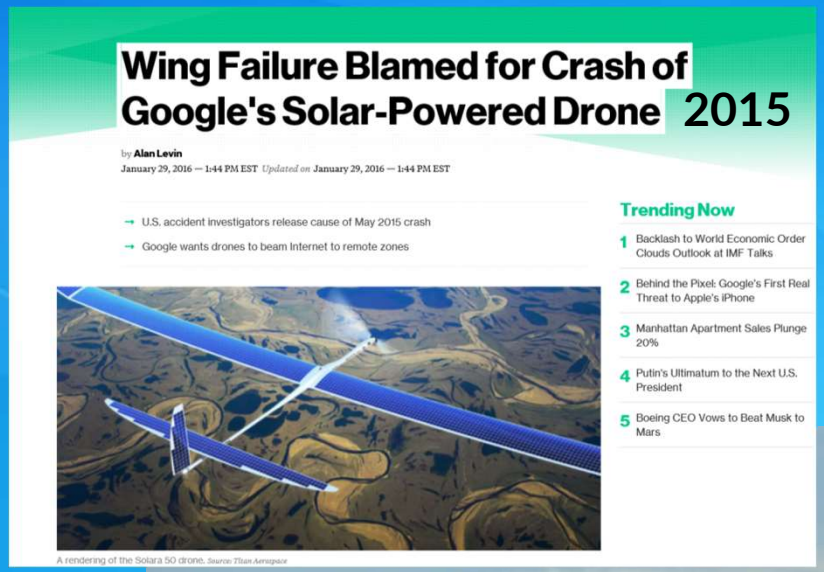


Risks



Wing Failure Blamed for Crash of Google's Solar-Powered Drone 2015

by Alan Levin
January 29, 2016 — 1:44 PM EST *Updated on* January 29, 2016 — 1:44 PM EST

- U.S. accident investigators release cause of May 2015 crash
- Google wants drones to beam Internet to remote zones

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A rendering of the Solara 50 drone. *Source: Titan Aerospace*

Possible Applications

Economy | Business and Economy

Is the stratosphere up for a gold rush?

A new generation of companies wants to use large, uncrewed aircraft to beam down 5G signals and keep an eye on Earth.

A new generation of companies is targeting the higher reaches of the Earth's atmosphere as the space closer to it has become increasingly crowded with satellites [File: Getty Images]

"We're seeing very interesting opportunities in this market", said Hussain Bokhari, a senior analyst at the research firm Northern Sky Research, which has conducted studies on the market for HAPS. It concluded in 2020 that by 2029, the market for stratospheric aircraft, which includes HAPS as well as balloons that use high altitudes for services like predicting the weather, would amount to $4bn in cumulative revenues.

It also predicted annual growth in revenues of 13 percent during that period. "It's going to be exciting to watch how the field develops", said Bokhari.

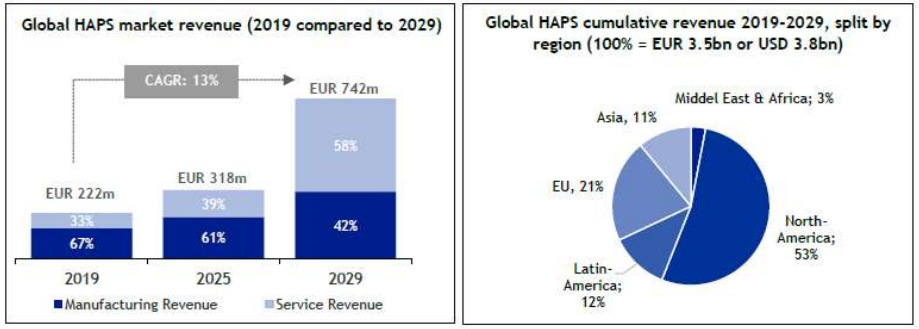


Figure 5: Global HAPS market revenue and global HAPS cumulative revenue

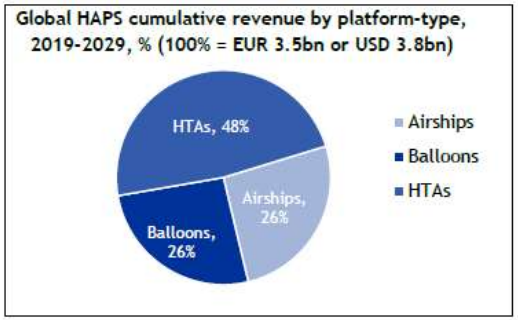
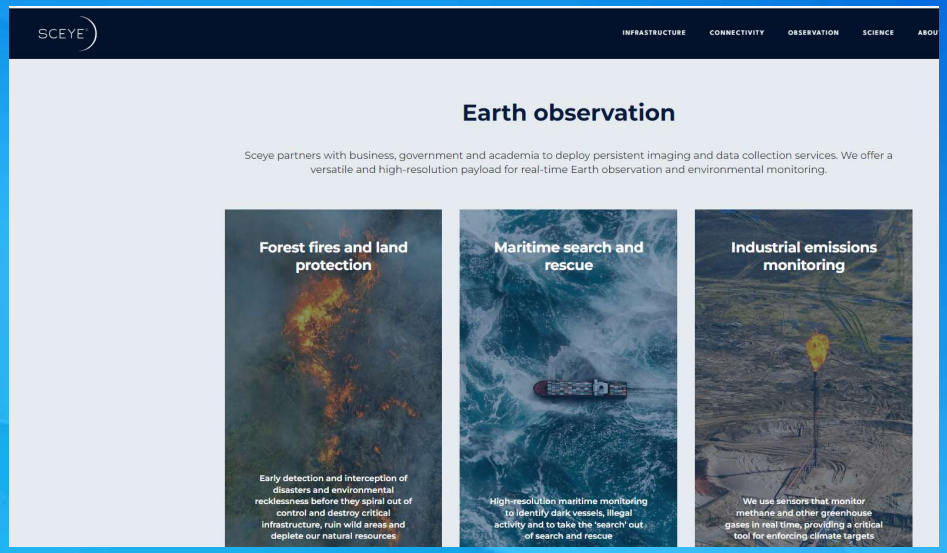
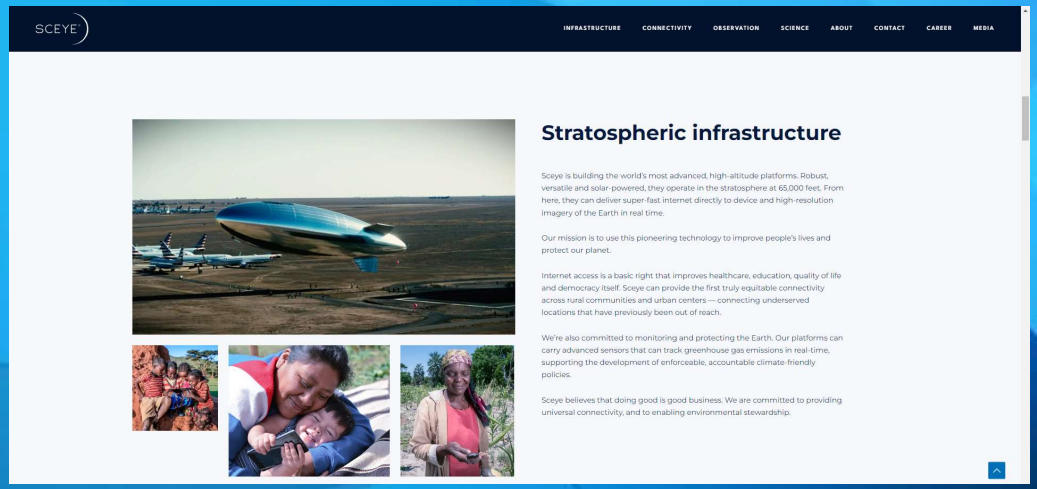


Figure 7: Global HAPS cumulative revenue by platform-type

Possible Applications





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Possible Applications: Earth Observation

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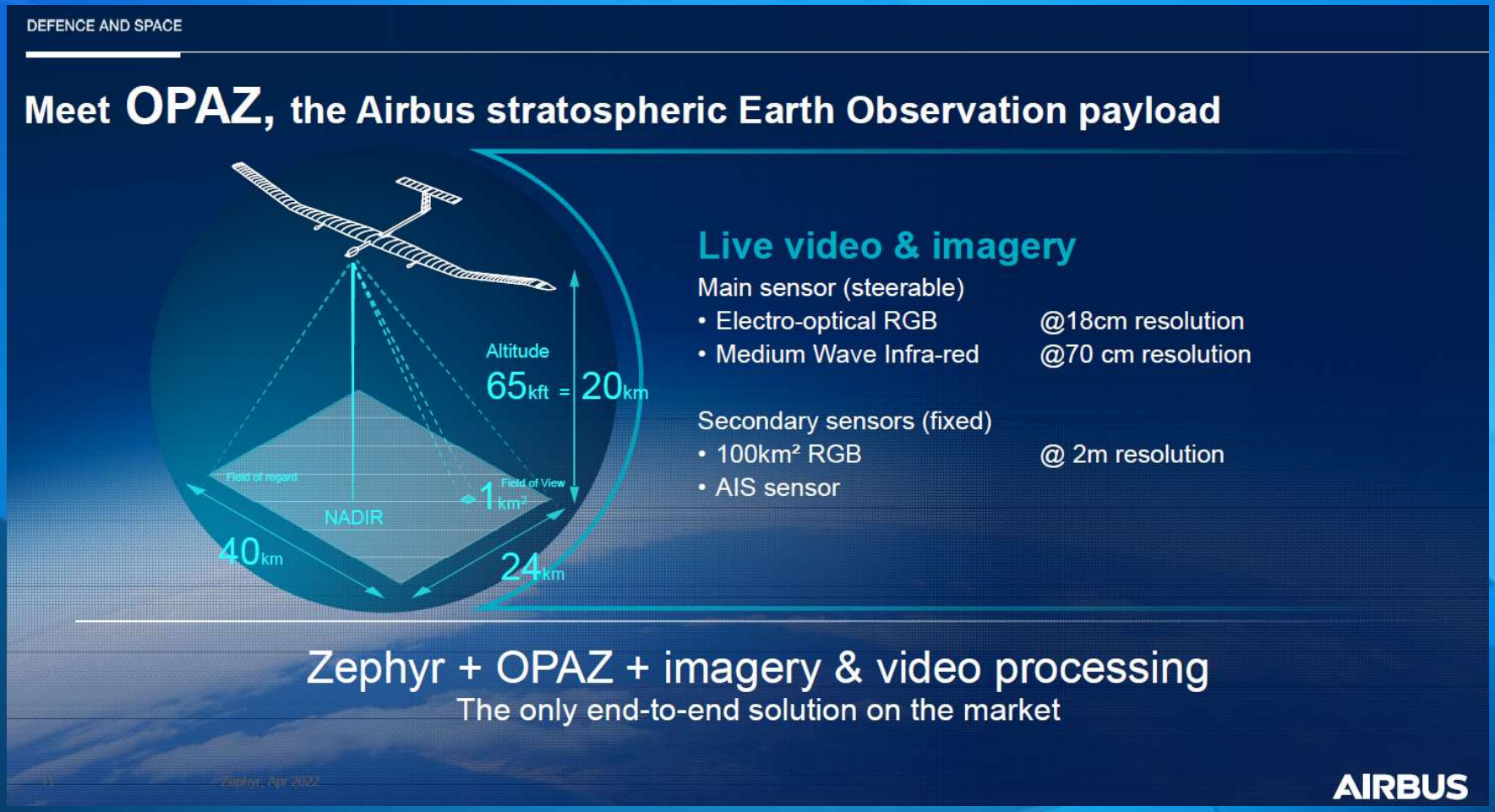
Possible Applications: Earth Observation

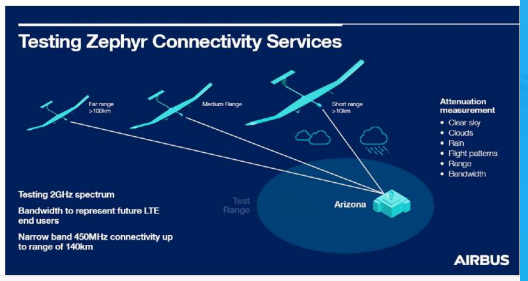


Possible Applications: Telecommunications

Zephyr connectivity trials from the Stratosphere

US, Aug. 2021:
Airbus and NTT DOCOMO successfully demonstrated the ability to use Zephyr to deliver future wireless broadband connectivity.

- Test deemonstarted various bandwidths to simulate direct-to-device service from the HAPS to end users using low, nominal and high throughput.
- The demonstration confirmed the viability and versatility of the 2GHz spectrum for HAPS-based services and also the use of a narrow (450MHz) band to provide connectivity in a range of up to 140km



17 Zephyr, Apr 2022

In 2017, when flooding in Peru and a major hurricane in Puerto Rico knocked out critical ground infrastructure, the Loon team navigated balloons to the disaster regions and provided emergency connectivity to hundreds of thousands of people. In 2018 Loon became an independent business within Alphabet and in 2020 the team co-founded the HAPS Alliance which aims to accelerate innovation and connectivity efforts in the stratosphere. In 2020, Loon launched the world's first internet-via-balloon service with partners to people in unserved regions of Kenya.

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Airbus' Aalto HAPS signs MoU with Bermuda's Paradise Mobile

New telco signs deal for new high-altitude technology

July 04, 2023 By: Dan Swinhoe Comment

Airbus' commercial high-altitude pseudo satellite (HAPS) unit has signed a deal with new Bermuda-based mobile operator Paradise Mobile.

Aalto HAPS this week announced it had signed a Memorandum of Understanding (MoU) to enter a strategic partnership with Paradise to introduce HAPS-based solutions to the region.

The companies said Paradise Mobile will have access to Aalto's solutions when the company rolls out commercial services in 2024. This will enable Paradise Mobile to provide connectivity services to a wide area from high altitude, and quickly provide additional coverage during emergency events.

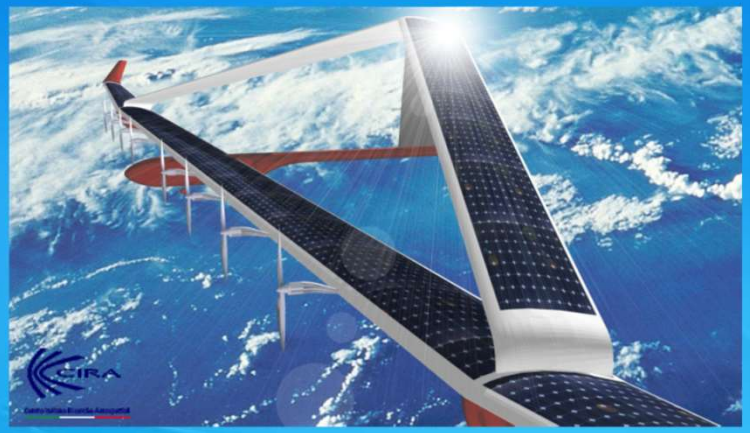
Samer Halawi, CEO of Aalto HAPS, said: "We are very pleased to count Paradise Mobile, the next-

CIRA's contribution to the state of the art of research on stratospheric platforms

V.Baraniello@cira.it

Centro Italiano Ricerche Aerospaziali

2002-2010
Heavy Lift Stratospheric Balloon Test



2006-2008
LVR –HALE project
Preliminary design of a HAPS Joined-wing

CIRA Activity on HAPS

CIRA PRORA
2020-2026
High Altitude Hybrid Airship Design, Realization and Flight-Demostration of a new concept of High Altitude Pseudo-Satellite

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Study on Application Requirements

Analysis of Payload Requirements

Optical – Hyperspectral – Infrared – Radar – 4G/5G Tras

Platform Requirements

Platform Requirements

Operative Environment

Airworthiness

Payload range	**15**-80 kg
Altitude	**18-20 km**
Energy System	Rechargeable Batteries with Solar Energy
Power	Propellers powered by Electric Engines
Cruise Airspeed	16 m/sec
Night Duration	15 h
Mass category	< 150 - 350 Kg
Mission Duration	4 months

Safety First

Easy Operation

Low Cost

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CIRA Hybrid High Altitude Airship

Buoyancy + Lift => Hybrid

- Efficency at low speed
- Intrinsically Safe
- Relatively small dimensions
- Good for medium payload
- Easy Operation
- Complex stucture design/build

- High Payload/MTOW
- Costs

- Low Mission Control
- No Long endurance

- High Efficency at low speed
- Intrinsically Safe

- Convenient only for high payloads
- Very complex ground operations

- Relatively small dimensions
- Good Payload/MTOW

- Aeroelastic problems
- Convenient only for low payloads
- Difficult take-off and landing

Hybrid Approach

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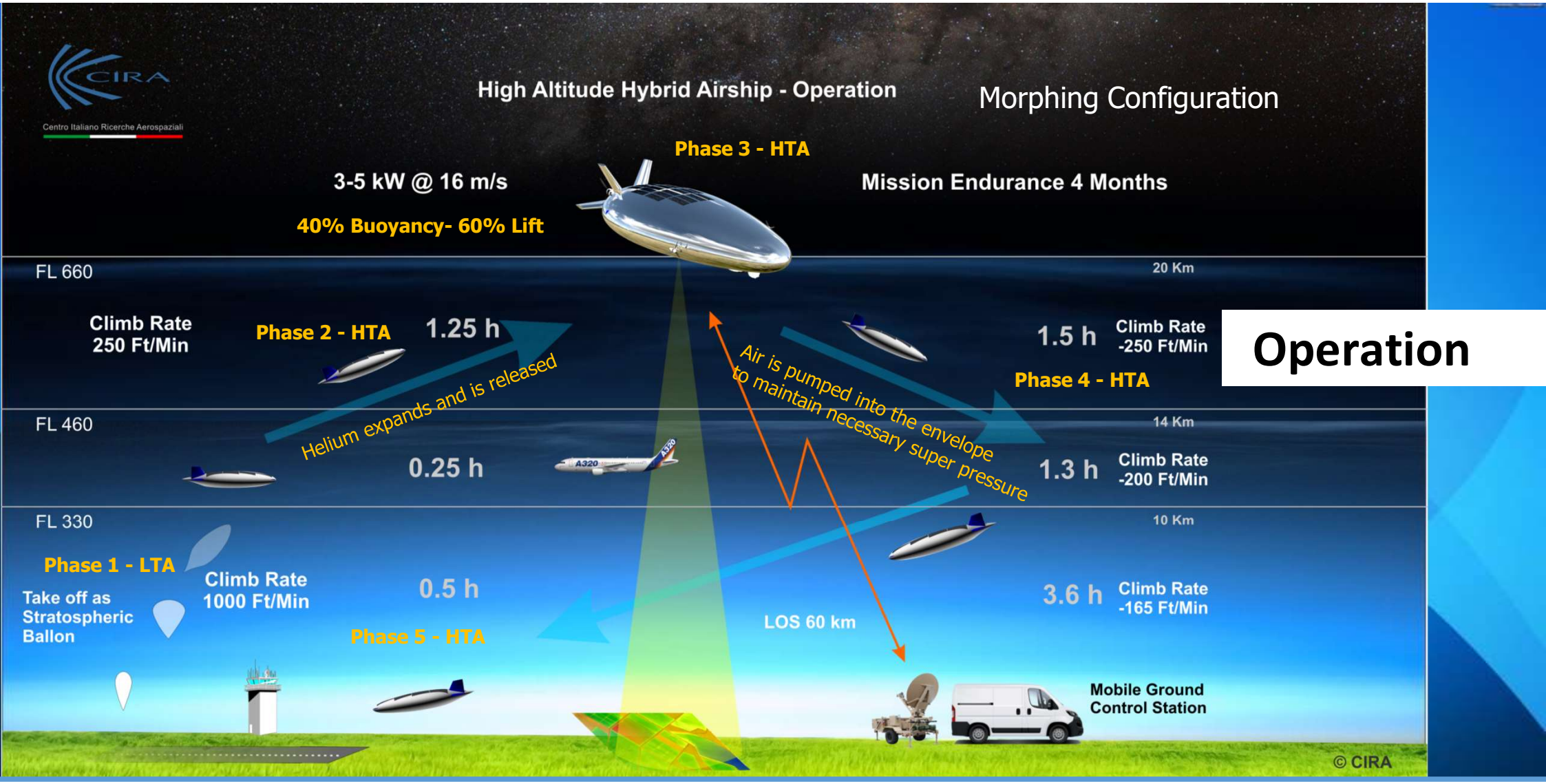
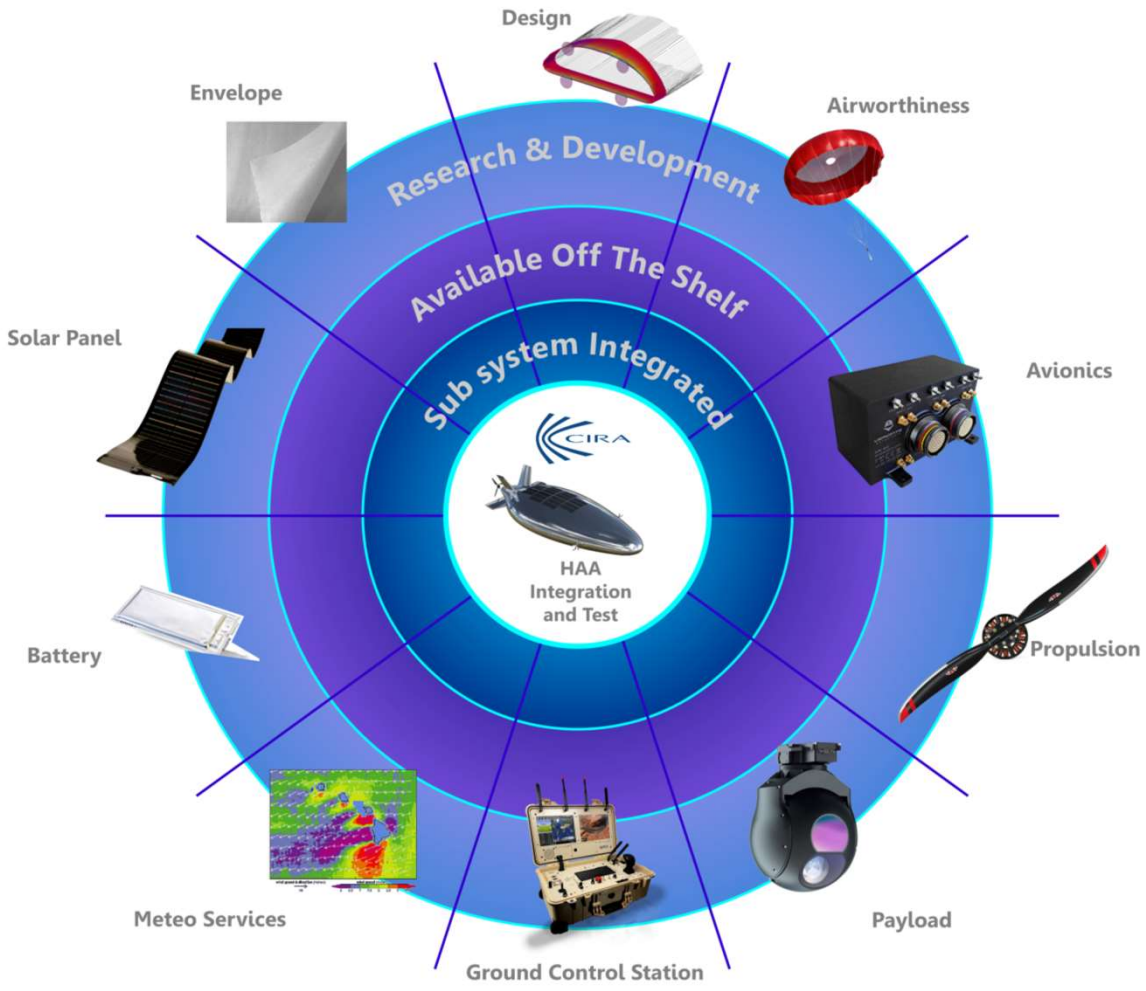

High Altitude Hybrid Airship - Operation
Morphing Configuration
Phase 3 - HTA
3-5 kW @ 16 m/s
Mission Endurance 4 Months
40% Buoyancy- 60% Lift
FL 660
20 Km
Climb Rate
250 Ft/Min
Phase 2 - HTA
1.25 h
1.5 h
Climb Rate
-250 Ft/Min
Phase 4 - HTA
Helium expands and is released
Air is pumped into the envelope
to maintain necessary super pressure
FL 460
14 Km
0.25 h
1.3 h
Climb Rate
-200 Ft/Min
FL 330
10 Km
Phase 1 - LTA
Take off as
Stratospheric
Ballon
Climb Rate
1000 Ft/Min
0.5 h
3.6 h
Climb Rate
-165 Ft/Min
Phase 5 - HTA
LOS 60 km
Mobile Ground
Control Station
© CIRA

Operation



- Inflatable Structures ;
- Membranes Laminates Material;
- Solar Power generation;
- Energy Management and Storage;

Key Technologies

- Electric Propulsion Systems;
- Innovative Payload;
- Avionics;
- Mobile ground segment.

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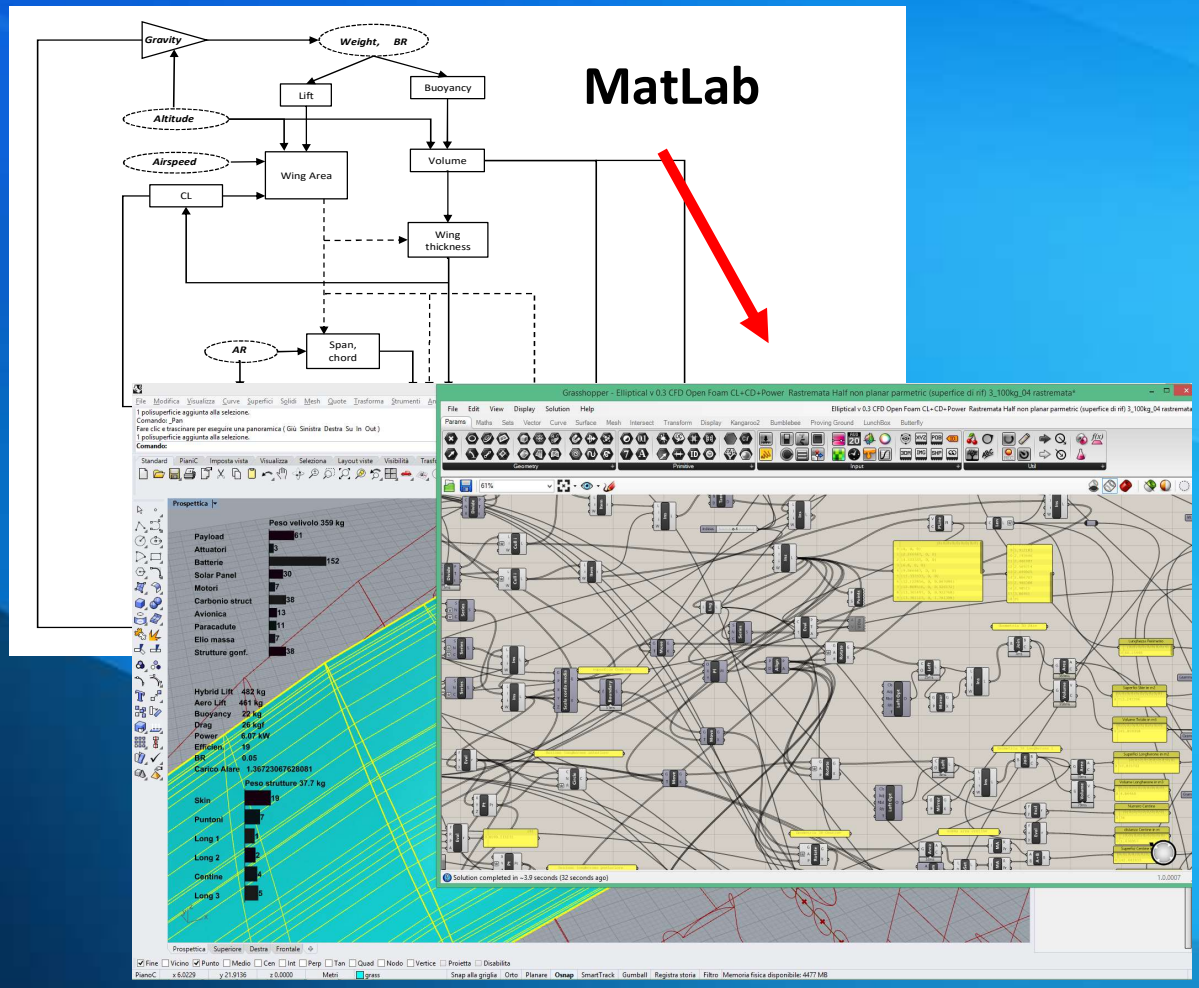

Conceptual design geometry modeler

Design loop for

- Fixed Wing
- Airship (no ballonet)
- Airship hybrid (no ballonet)

CIRA HAPS Conceptual Design

Interface to:

→ CFD → Stability

→ FEM

→ Carat. Material

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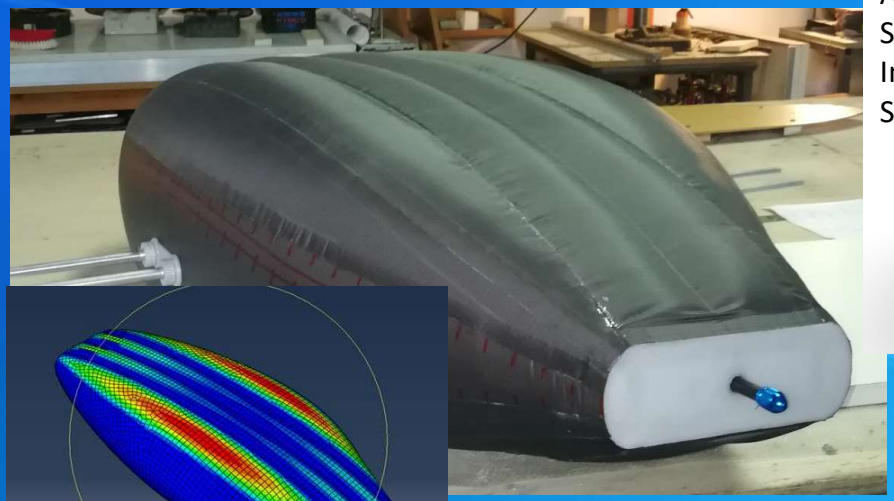

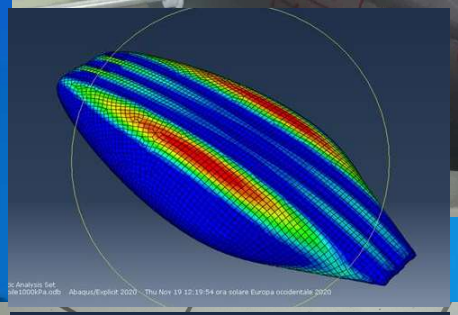

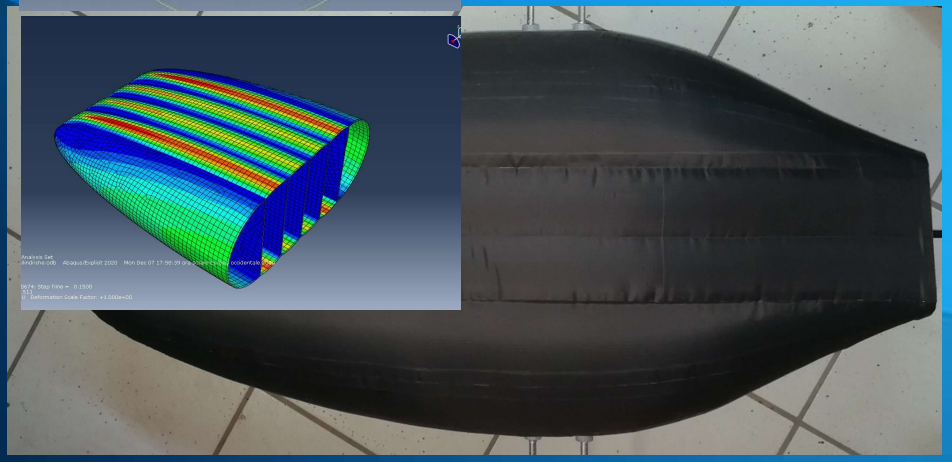

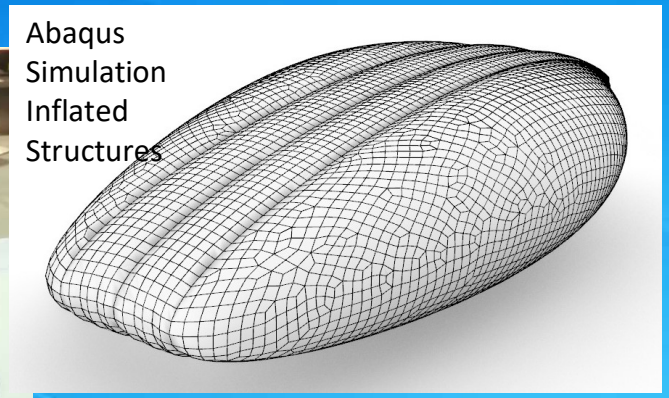

Inflatable Structures

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Helium leaks in one year up to 10-15% total volume

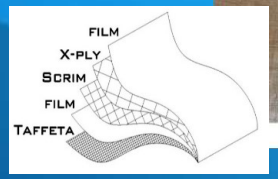
Fiber	Type	Source	Density (lb/in.^{3})	Strength (10^3 psi)	Modulus (10^6 psi)	Strength to wt (10^6 in.)	Break strain (%)
Dacron	Polyester	DuPont	0.050	168	2	3.4	14
Nylon	Polyamide	DuPont	0.042	143	1	3.4	18
Kevlar	Aramid	DuPont	0.052	435	16	8.4	2
Vectran	Liquid Crystal Polymer	Kuraray	0.051	450	10	8.9	3
Spectra	UHMWPE (S-2000)	Honeywell	0.035	484	18	13.8	3
Carbon	PAN (T1000)	Toray	0.065	924	43	14.2	2
Zylon	PBO	Toyobo	0.056	840	26	15.1	3
Dyneema	UHMWPE	DSM	0.035	536	26	15.3	3–4
S-Glass	Fiberglass (S-2)	Owens Corning	0.090	665	13	7.4	5
Titanium	(Ref)		0.160	155	17	1.0	6

Material

ZYLON

Vectran

Dyneema®
With you when it matters



da 400gr/m2 → **a 60gr/m2**

Polyurethane — Dyneema UHMWPE

SkyShip 600	lunghzza 60m diametro 15.3m
materiale 400gr/m2	
resistenza 37kN/m	3700Kg/m

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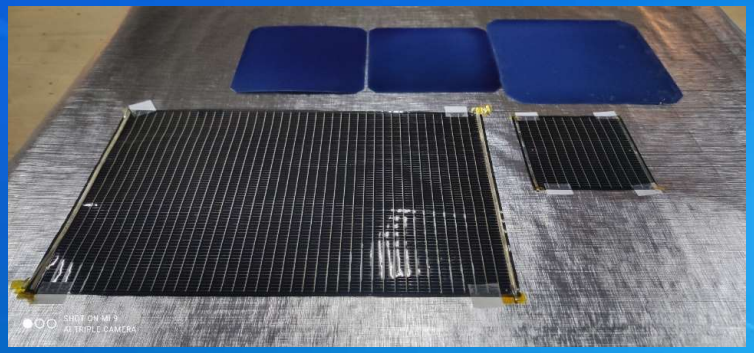


Energy subsystems

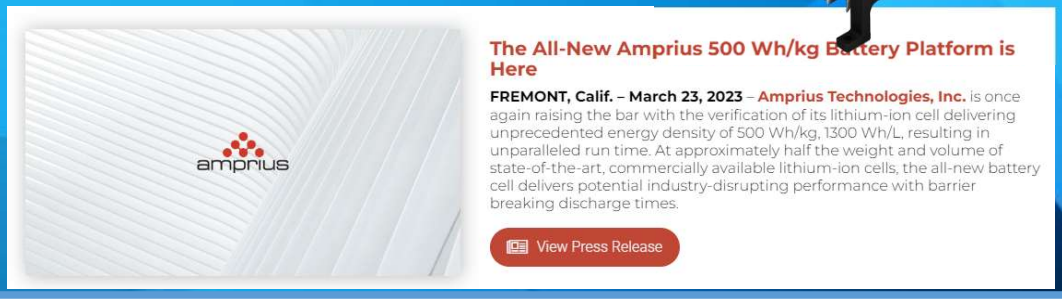
Thin GaAS Flexible Solar Cells with energy densities greater than 1 kW per kg with efficiencies of 28-30%
Very high costs around 100 euros x Watt

GIGS Flexible Solar Cells with 10-15% efficiencies0.8-1.1 kW per kg | costs 30 euros per Watt

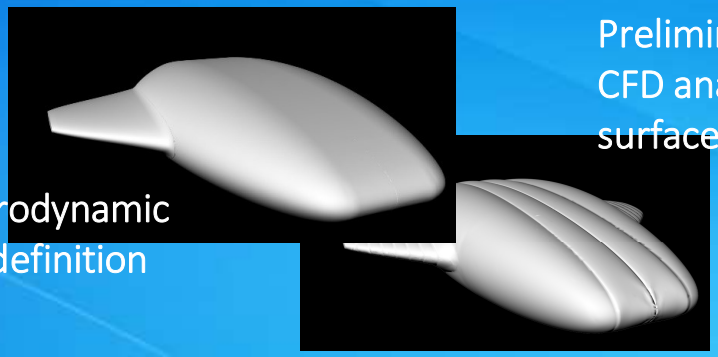
Electric motors Power on Weight approx. > 5 kW/kg

Sion Power®

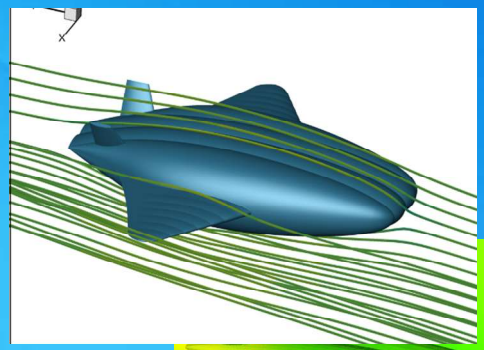
Battery Lipo-Me 500 Wh/kg

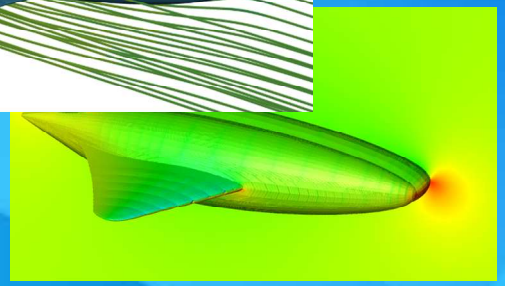


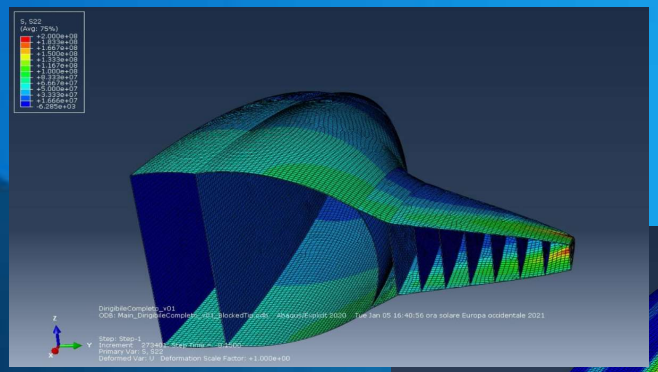
Conceptual Aerodynamic Configuration definition

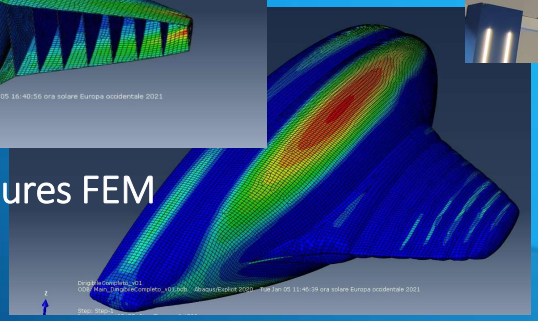


Preliminary aerodynamics CFD analysis with deformed surfaces









Inflatable structures FEM simulation

Inflatable structures scaled protype

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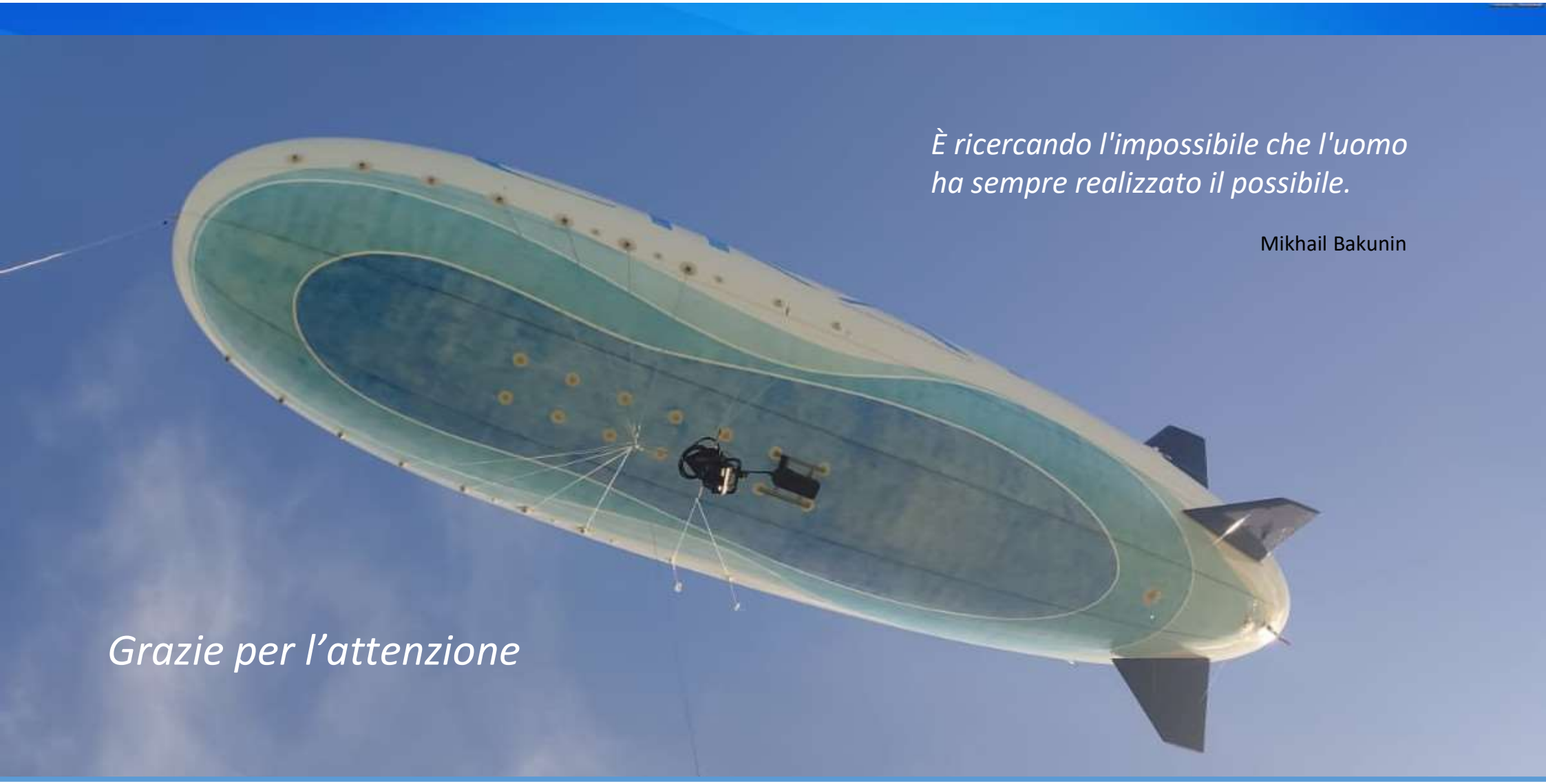

È ricercando l'impossibile che l'uomo ha sempre realizzato il possibile.

Mikhail Bakunin

Grazie per l'attenzione

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