



Sapienza University of Rome

School of Industrial and Civil Engineering - Via Eudossiana 18 - Roma

Wednesday

24 October 2018 • 14:00

Hypersonic Flight:

Challenges, Opportunities and Implications, an Overview



Lecture given by

G^{al} Giuseppe CORNACCHIA

Hypersonic Flight coordinator, Associazione Arma
Aeronautica Sezione Roma Due "L.Broglio"



SAPIENZA
UNIVERSITÀ DI ROMA



SEZIONE ROMA DUE
LUIGI BROGLIO
ASSOCIAZIONE ARMA AERONAUTICA

More information on:

www.academie-air-espace.com



Hypersonic Flight: Challenges, Opportunities and Implications, an Overview

Sapienza University, Rome, October 24, 2018

G. Cornacchia

Associazione Arma Aeronautica, Sez. Roma Due “L.Broglio”

g.cornacchia@romadue-broglio.eu

Caveats:

- ✓ **Main focus: atmospheric propelled hypersonic flight**
- ✓ **Commonalities with space flights**
- ✓ **Suborbital flights**

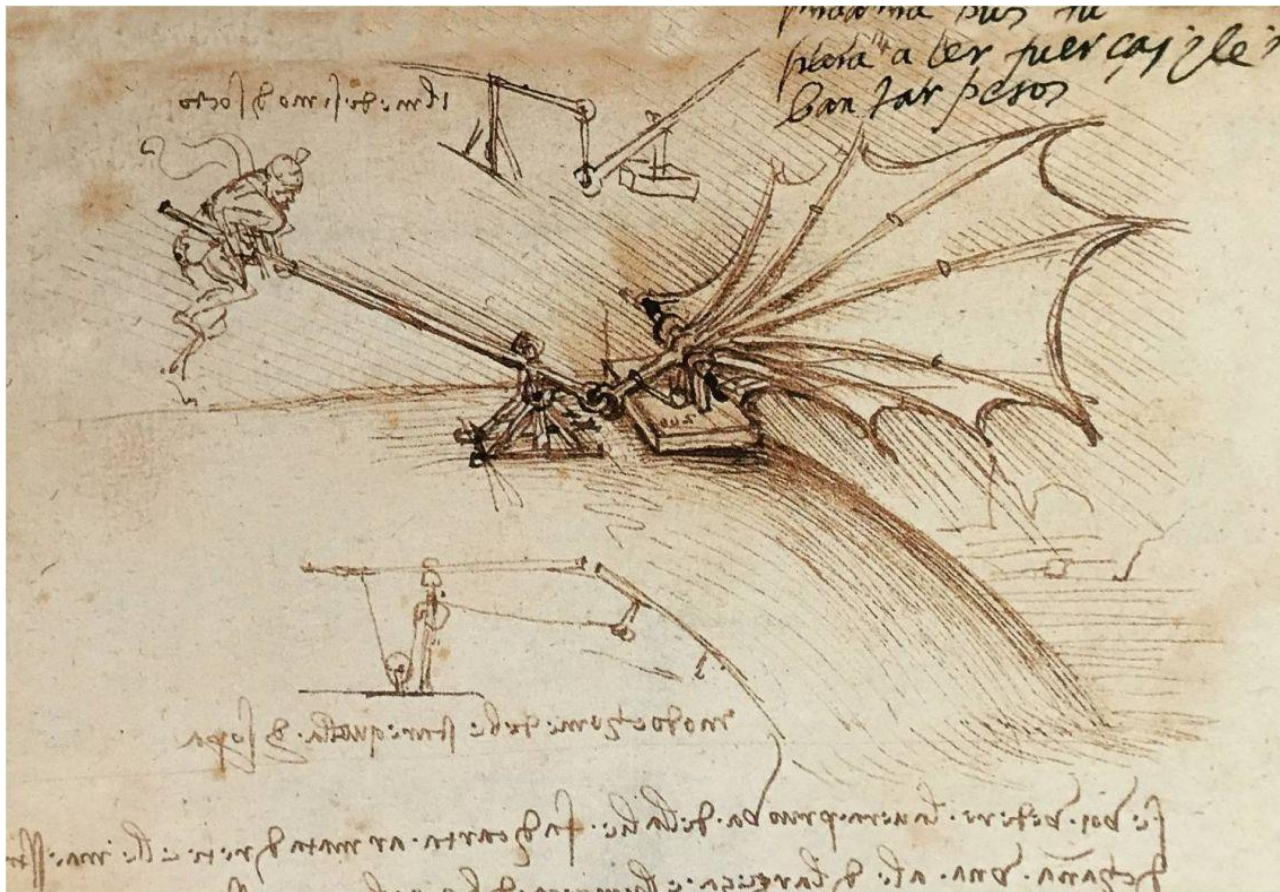
- ❖ **Brief historical background**
- ❖ **Selection of recent/current projects concerning hypersonic transportation/weapons**
- ❖ **Enabling technologies and concurrent areas**
- ❖ **Considerations**
- ❖ **Conclusions**



Icarus falling (on a wall painting from Pompeii, about 79 AD)



**Carlo Saraceni, Caduta di Icaro (1606-07),
Napoli, Museo Nazionale di Capodimonte**



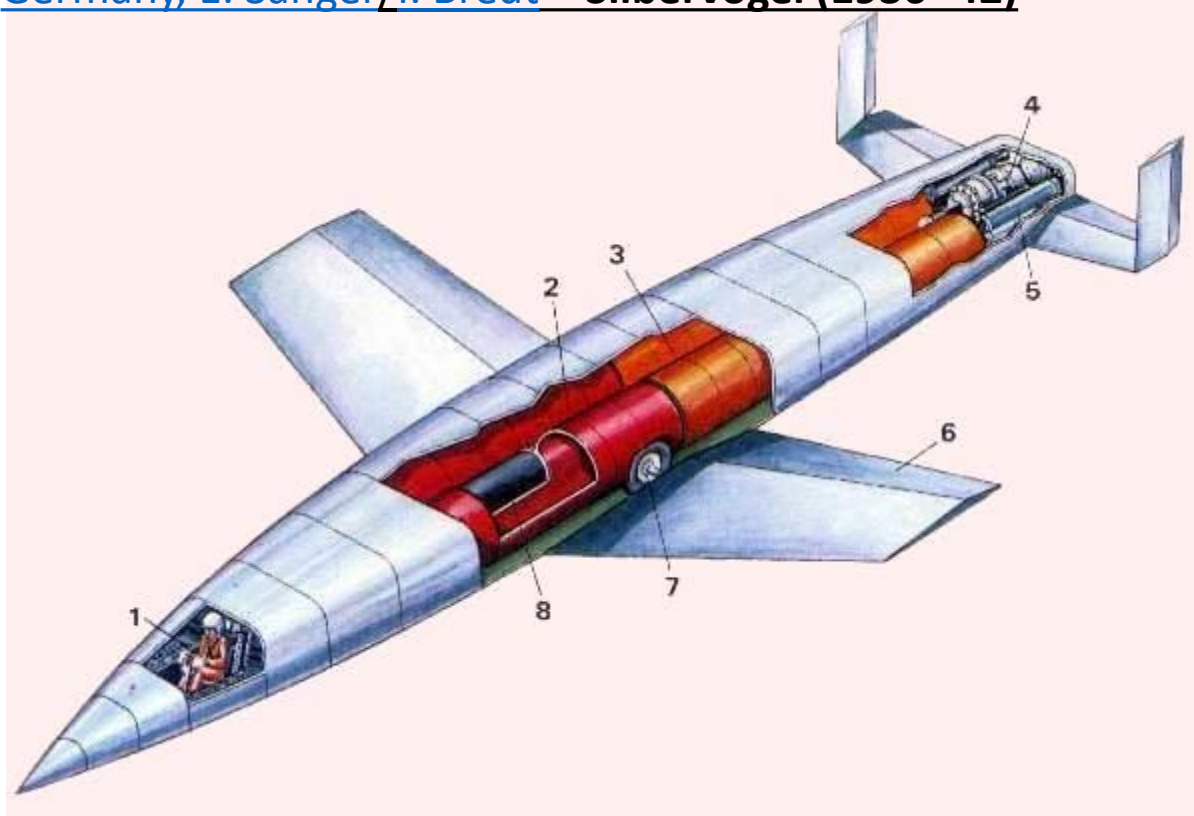
Leonardo da Vinci (1452-1519)

The Flyer



Wilbur and Orville Wright, Kitty Hawk, December 17, 1903

Germany, E. Sänger/I. Bredt – Silbervogel (1936-'42)



- 1) Pressurized Cockpit 2) Oxidant Tanks 3) Fuel Tanks 4) High-Pressure Combustion Chamber of 100 Tons Thrust**
5) Auxiliary Rocket Chambers 6) Wedge-Shaped Wing 7) Retracted Undercarriage 8) Free-Falling Bomb

Germany, Silbervogel, 1936-'42

- **Spaceplane, 3 km sled TO**
- **Never built**
- **Rocket motor, 90 t**
- **Mach 18 (22.100 km/h)**

USA, Bell X-1, October 14, 1947



Mach 1,06 (1 127 km/h, 700 mph, 608 kts), [Chuck Yeager](#)

USA, North American, X-15, 1954-1968



Record Mach 6.7 on Oct. 3, 1967, Air Force pilot Pete Knight

- ✓ **First hypersonic controlled flight**
- ✓ **Project, 1954 (NACA, US Air Force and Navy)**
- ✓ **Rocket engine, 57,000 lbs**
- ✓ **aerodynamic controls/reaction control system**
- ✓ **outer skin of a nickel-chrome alloy (Inconel X)**
- ✓ **Altitude record: 354,200 feet (on Aug. 22, 1963, NASA pilot Joseph Walker)**

Boeing X-20 Dyna-Soar, 1957-1963



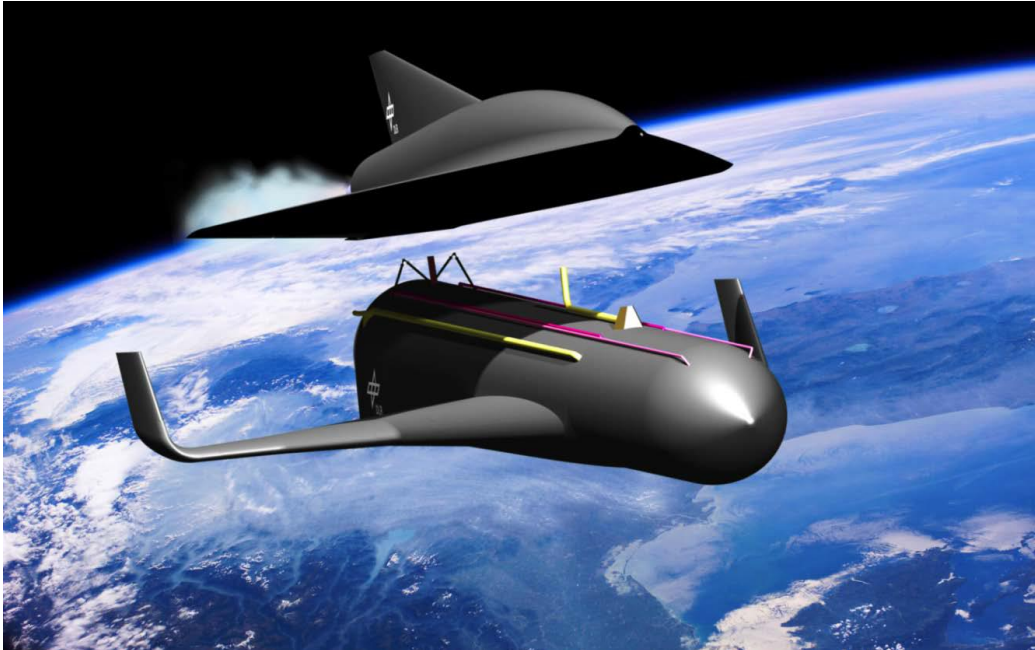
Spaceplane never built, apparently inspired by the Silbervogel

Germany, SpaceLiner, 2005-



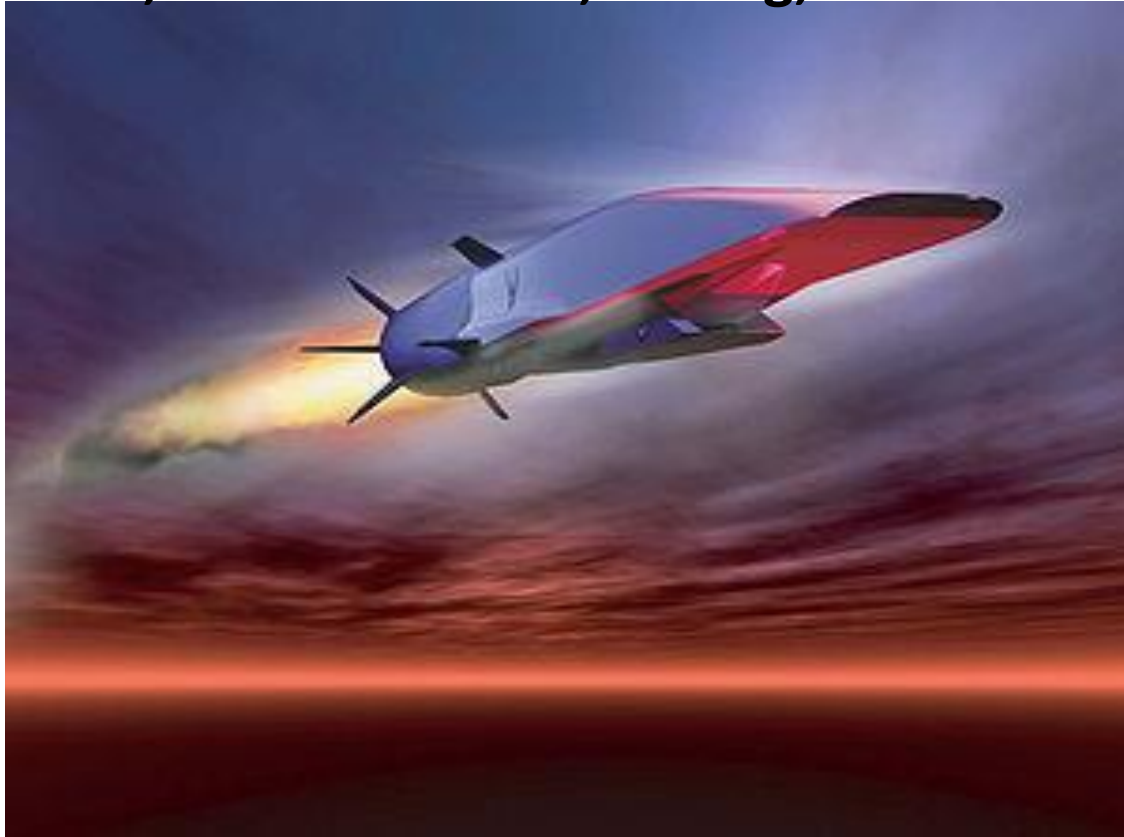
- **Visionary Ultra-fast Passenger Transport**
- **2-stage rocket-propelled fully reusable vehicle**

Germany, SpaceLiner, 2005-



Vertical lift-off and horizontal landing

USA, X-51 Waverider, Boeing, 2005-2013



**Unmanned, scramjet experimental aircraft
2013, Mach 5.1 (5400 km/h), 210 secs (total flight 6 min)**

Italy, Hyplane, Trans-Tech/Federico II University, 2013-



**Italy, Hyplane, Trans-Tech/Federico II University
feasibility study for :**

- **6 passengers**
- **TBCC/RBCC - HTHL**
- **Mach 4.5, 6.000 km**
- **access to suborbital space and point-to-point stratospheric flights**

Japan et al., HIKARI Project, 2013-

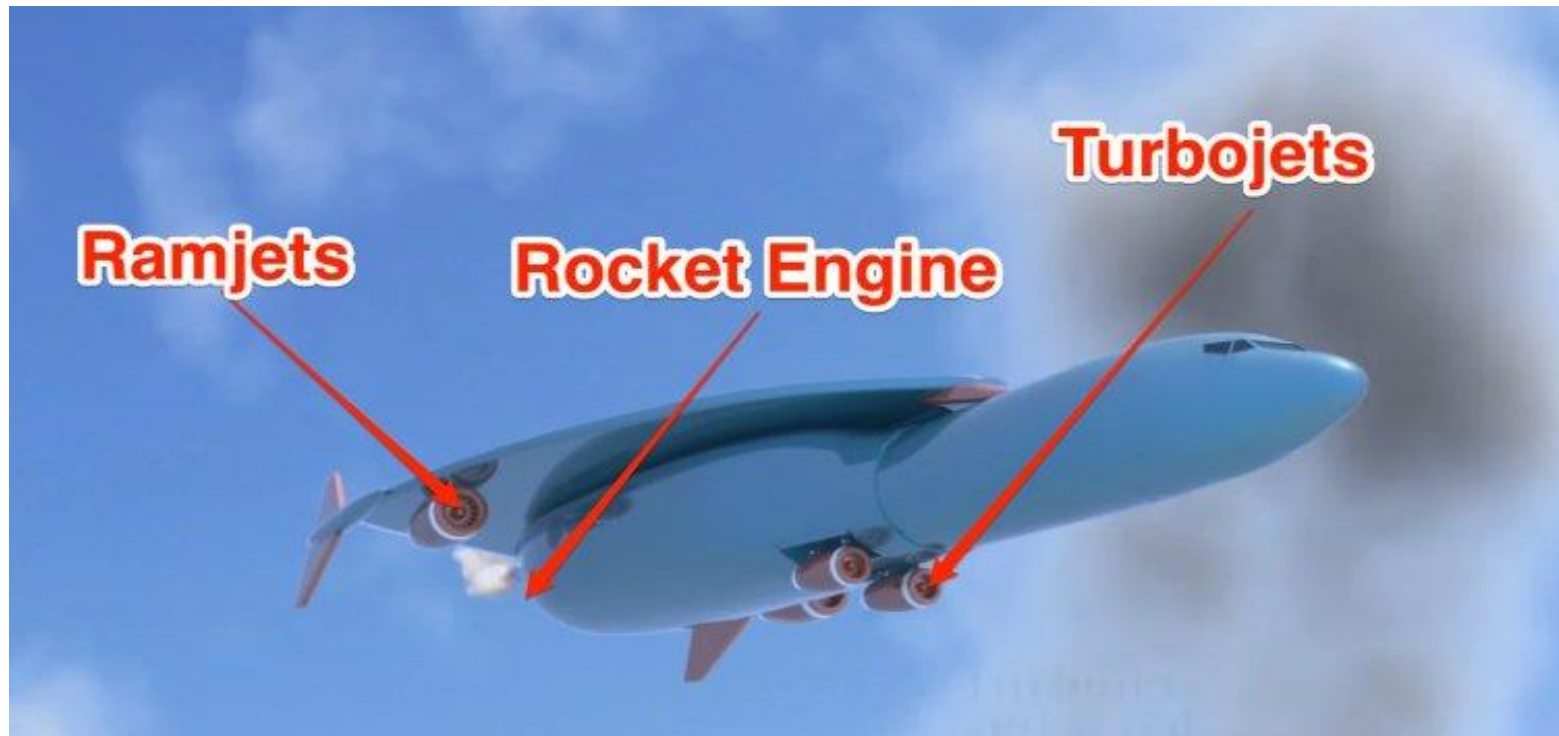


Japan et al., HIKARI Project, 2013-

An incremental way, towards

- ☐ **100 pax vehicle**
- ☐ **Mach 5**
- ☐ **14.000 km range aircraft**
- ☐ **Possibly using cryogenic fuel**

AIRBUS, 2015-



Dubbed Concorde 2

AIRBUS, 2015-

- ✓ **20 passengers**
- ✓ **HOTOL, T/RBCC**
- ✓ **Mach 4.5, altitude >100,000 ft**

UK, Skylon, Reaction Engines Ltd, 1989-



UK, Skylon, 1989-

- **Passengers/cargo**
- **Unmanned, SSTO, HOTOL**
- **Mach 5+ atmospheric, 25+ space**
- **hybrid air-breathing rocket engine (SABRE) – T/RBCC**
- **cooling rates of 1,000 °C in 20 milliseconds**
- **First test of the Sabre engine in 2020, first flight in 2025**

USA, Boeing, 2018-



**Boeing, debuts first passenger-carrying hypersonic vehicle concept
June 26, 2018 - could be airborne in 20 to 30 years (Kevin Bowcutt, X-51)**

USA, HCSW/ ARRW, Lockheed Martin, 2018-



**Hypersonic Conventional Strike Weapon (HCSW)
Air-Launched Rapid Response Weapon (ARRW)**

- **Hypersonic Conventional Strike Weapon (HCSW), \$928m contract in April 2018**
- **Air-Launched Rapid Response Weapon (ARRW), \$480m (August 2018), development to be completed by November 2021**
- **May 2013, USAF planned to apply X-51 technology to the High Speed Strike Weapon (HSSW)**
- **HSSW could fly in 2020 and enter service in the mid-2020s, range of 500-600 nmi, Mach 5-6, on [F-35](#) or internal bay of a [B-2](#)**

USA, SR-72?, Lockheed Martin, 2013-



- SR-72, hypersonic UAV intended for ISR**
- Mach 6, TBCC, HOTOL**
- Not expected to be operational until 2030**

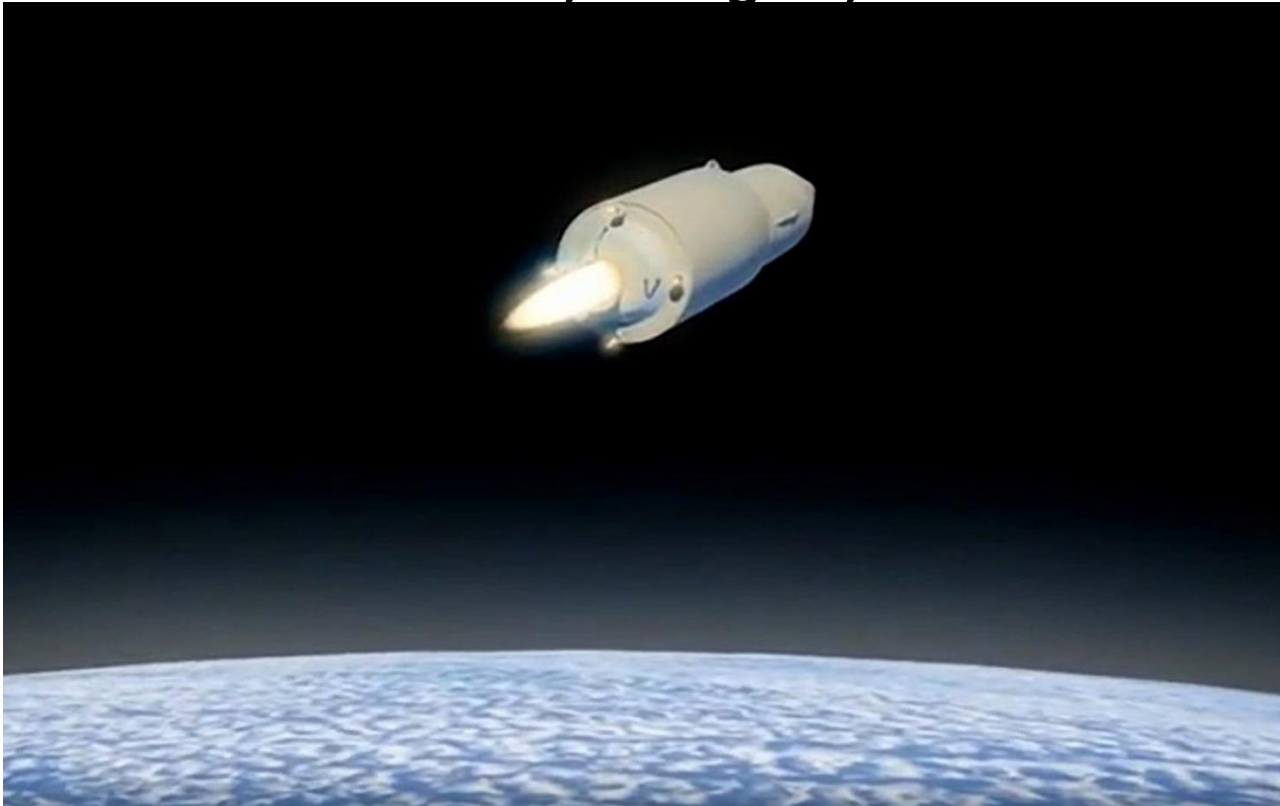
CHINA, Xingkong-2 (Starry Sky-2) 2018



CHINA, Xingkong-2 (Starry Sky-2) 2018

- **Successfully tested on Friday, August 3, 2018 (China Daily)**
- **China's first experimental hypersonic waverider vehicle, is launched inside a rocket**
- **Mach 6**
- **“Could one day be capable of firing nuclear missiles”**

Russian Federation, Avangard, ? - 2018



Credit: Ministry of Defense of the Russian Federation

Russian Federation, Avangard, ? - 2018

- **Can apparently reach Mach 20**
- **Rocket launched, then hypersonic glide,**
- **maneuverable, depressed trajectory**
- **Nuclear tipped**

Russian Federation, Kinzhal, ? - 2018



- May 9, 2018, Victory Day Parade onboard newly modified MiG-31K
- Nuclear and conventional warheads, range >2,000 km, Mach 10
- Air launched ballistic missile

Priorities

- ☐ **Propulsion (combustion, solid/liquid propellant, etc.)**
- ☐ **Managing the thermal stresses of high-temperature cruise**
- ☐ **System integration (GN&C, HMS, etc.)**

- ❖ **Norms and regulations**
Harmonize global/regional/national regulations (International Civil Aviation Organization (ICAO), European Aviation Safety Agency (EASA), United Nations Office for Outer Space Affairs (UNOOSA))
- ❖ **Expand/harmonize national legislation to cover new activities**

- ❖ **Air Traffic Management (ATM) adaptation to integrate hypersonic/space flights**
- ❖ **Safety in operations, both in flight and on the ground (safety by design)**
- ❖ **Environmental protection**
- ❖ **Infrastructures**

- **EU support/cooperation (ESA, EU, national space agencies, industries, academia)**
- **International cooperation**
- **Promote national awareness on benefits**

Looking at the wider picture

- **2014, Chinese tests of a hypersonic glider detected and followed by others**
- **2016, classified report by the National Academies of Sciences warns about the US falling behind in hypersonics**
- **2017 21st International Space Plane and Hypersonic Systems and Technology (AIAA) conference presented Chinese progress in hypersonics**
- **2018, US budget allocations for hypersonic weapons increase**
- **Upcoming International Conference on High-Speed Vehicle Science and Technology in Moscow will provide more details on the Russian progress**
- **A clear trend is emerging**

Looking at the wider picture

- **Another perspective is also taking shape!!**
- **2017, Treaty on the Prohibition of Nuclear Weapons adopted**
- **2017, RAND Corp. report warns on hypersonic missiles proliferation, implying similarities with nuclear weapons**
- **It is a fact that kinetic energy released on impact by hypersonic weapons approaches a small nuclear charge**
- **Although nuclear weapons will remain as weapons of last resort, their use is hardly plausible and strongly opposed by constituencies**
- **Hence, conventional hypersonic weapons will acquire relevance and likely replace their role of deterrence**

- **Enabling technologies have been extensively explored**
- **Hypersonic weapons, less technologically demanding, may lead but transport remains a basic goal and will follow closely**
- **Simplifying exit and re-entry into the atmosphere will also benefit space activities**
- **Global peace and stability may be affected if uneven capabilities prevail**

You are kindly invited to attend our

3rd International Symposium on

Hypersonic Flight

May 30-31, 2019

Follow us on

www.romadue-broglio.eu

Thank You!!

