BIOMIMETIC APPROACHES TO SELECTED NASA AERONAUTICS TOPICS:

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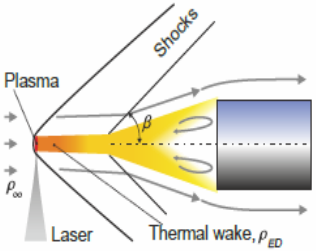
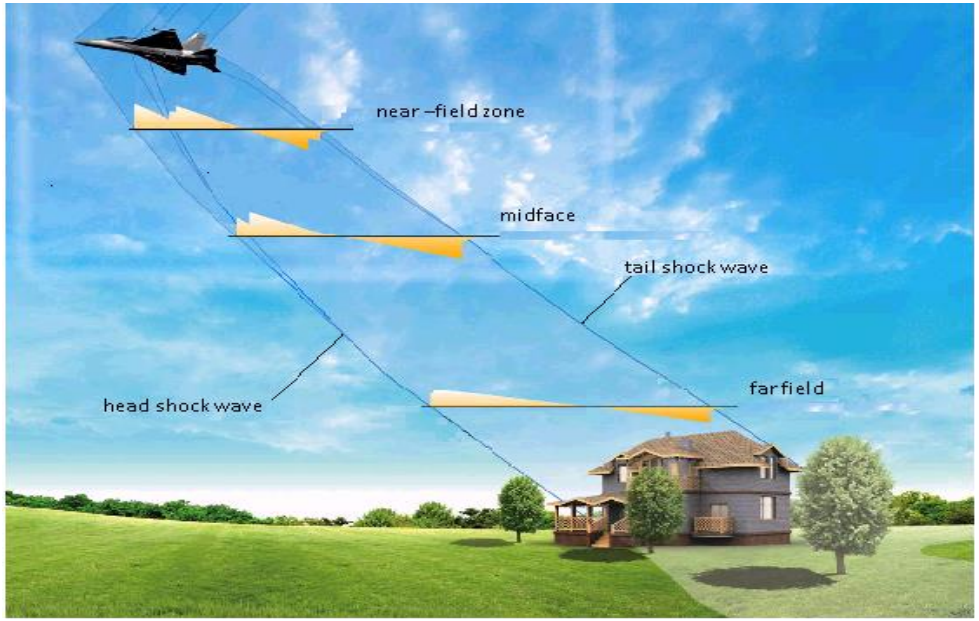




Presentation :

University of Akron.

February 26, 2016

BIOMIMETIC APPROACHES TO SELECTED NASA AERONAUTICS TOPICS

Topics of Discussion

(1) A Penguin-Inspired Torpedo: Forward Energy Deposition for Active Flow Control: Sonic Boom mitigation

(2) Rattlesnakes/Pit Vipers/Boas and Infrared vision (Multi-sensor data fusion)

(3) Saguaro cactus (South American)-surface feeder root system-Wind/Water-induced vibrations: Methods of suppression

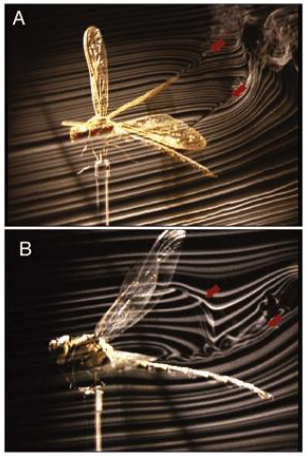
(4) The Wellington (WWII Bomber (RAF): Isogrid Structures vs Monocoque_-_shock-absorber-impact resistance

Opportunities for Expanding the Range of Aeronautical Inquiry

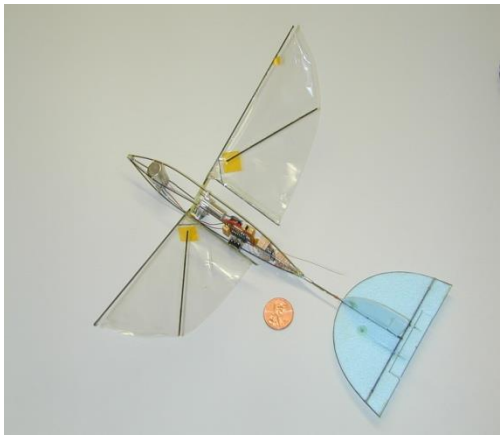

Extremes in Variable Geometry Wings

Formation Flight

Solar Powered Flight



Unsteady Aerodynamics

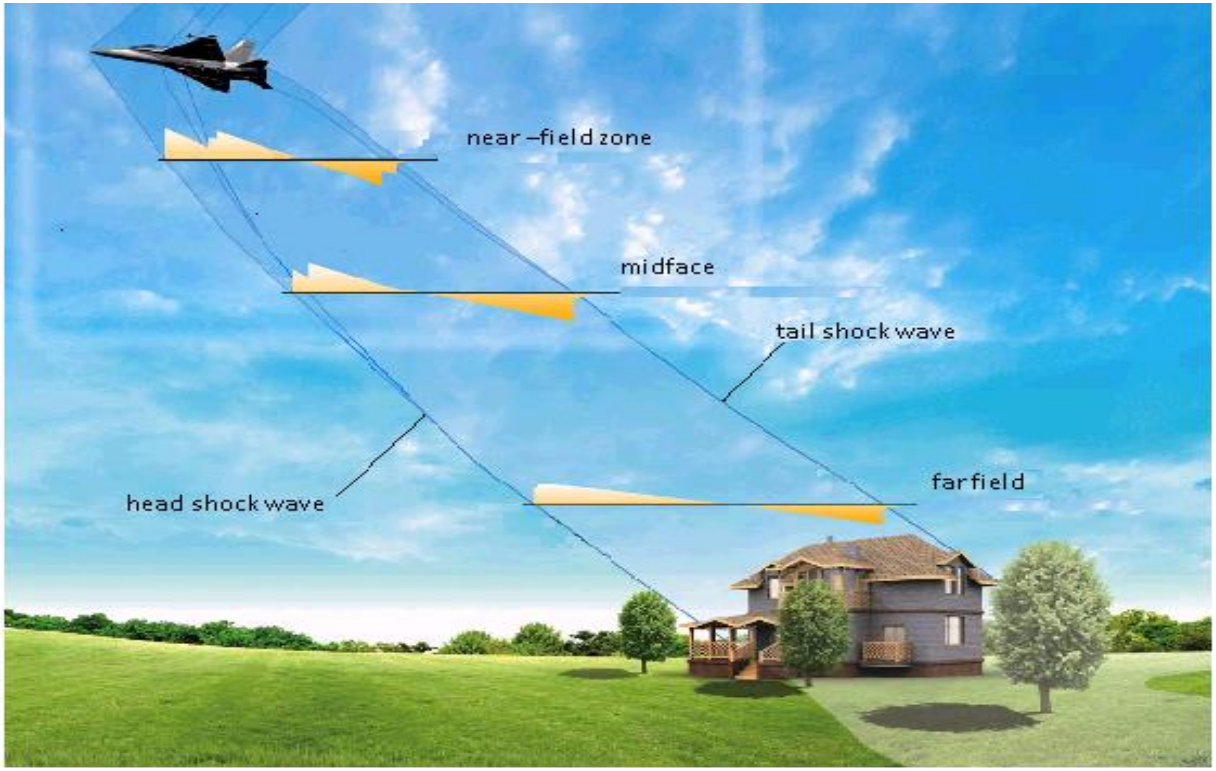


Micro Air Vehicles (µAVs)

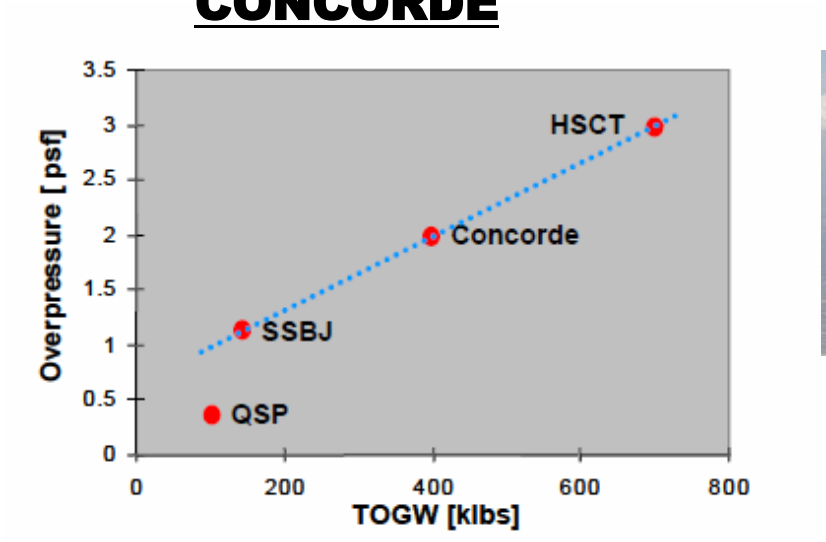
Ultra-Quiet Flight

Supersonic Flight and the Sonic Boom Problem

- Shock waves form around vehicles traveling faster than the local sound speed
- The propagation of the shock wave to the ground results in the occurrence of the well known sonic boom
- The sonic boom is a manifestation of the deposition of acoustic energy associated with the shockwave into ground structures—leading to damage and extreme noise pollution
  - Broken windows, insane cattle, cracked plaster, freaked out people and pets!
- The sonic boom problem is what has hampered the development of civilian supersonic transport
  - Concorde flight paths were severely restricted.



Low Sonic-Boom Design Capabilities Have Progressed Since CONCORDE



Concorde (1979-2003)	HSCT/HSR Program (1990's)	QSP Program (2001-2003)
Max Overpressure ~ 2.0 psf	Max Overpressure ~ 2.8 psf	Max Overpressure ~ 0.3 psf
Max Takeoff Wt ~ 400 klbs Length = 202 ft	Max Takeoff Wt ~ 700 klbs Length = 326 ft	Max Takeoff Wt ~ 100klbs Length = 130 ft
Not designed for low sonic boom	MDO/CFD Shape Optimization Demonstration	Boom Reduction Technologies
Land-restricted supersonic flight.	Boom prediction improved (SR-71 Experiments)	CFD Shape optimization for boom. SSBD Shaped Signature Demonstrated.

Figure of Merit : $\mathrm{FoM} = [\beta W/(P_g t^{3/2}\sqrt{h})]e^{h/(2H)}10^3.$ **FN (Weight, Length, Altitude, Speed, Shape, etc)**

Mitigation of the Sonic Boom—Recent Efforts

A renewed interest in supersonic flight spurred on mostly by Gulfstream efforts to develop a practical **low-boom supersonic business jet**, has included laboratory and flight demonstrations. Grumman (QSP 2003).

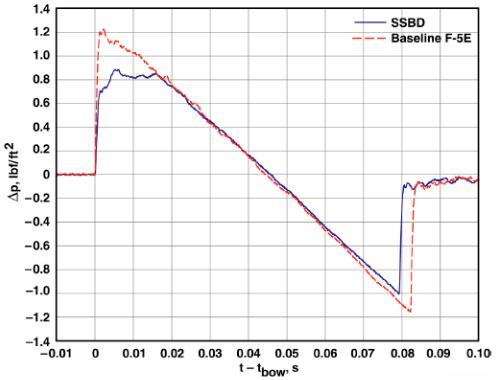
Currently: Intensive CFD/experimental optimization work pursued by NASA, DARPA, and US industry (Boeing, Lockheed, etc) and in Europe, Japan, and Russia.

Most of this work has focused on the use of **passive shaping and optimization** to generate unconventional airframes, and the use of passive components that modify, deflect, or weaken shocks

Issues: Aircraft weight/length relationship, and the **area distribution** paradox for low drag (high aerodynamic performance) and low boom signature must be addressed simultaneously.

Shaped sonic boom experiment

Quiet Spike



Sample N-Wave Sonic Boom Signature

Current Efforts in Development of Commercial Supersonic Aircraft

Advantages of Supersonic Flight

- Fast flight from departure to destination
- Fast accomplishment of critical missions
  - Relief efforts during natural disasters
  - Medical emergencies
- PROBABLE increase in safety and stability during turbulent flight

Spike Aerospace is building a new supersonic private jet

http://www.breitbart.com/blog/2014/02/19/new-supersonic-jet-tricked-out-with-massive-live-streaming-screens/

Supersonic Private Jet by Aerion

http://www.apollojets.com/supersonic-private-jet-by-aerion-will-change-aviation-as-we-know-it-executive-jet-charter/

HyperMach SonicStar

Lockheed Martin conceptual design

Conceptual design

LAPCAT A2, Reaction Engines, UK

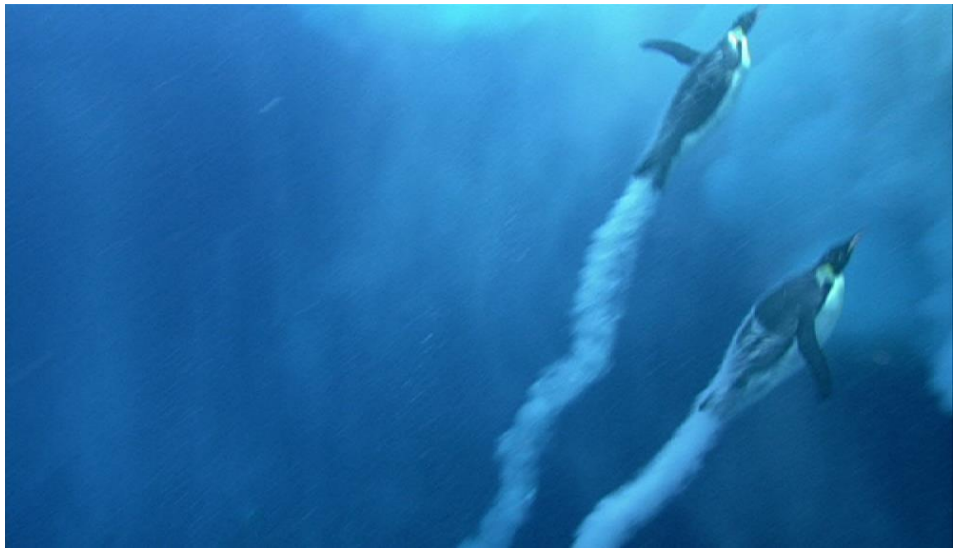
QSST, Aerospace International

EMPEROR PENGUIN

Forward energy deposition, **Active Flow control,** Thermal management, Sonic boom mitigation

EMPEROR PENGUIN

Forward energy deposition, Active Flow control, Flow modification, Drag reduction, Thermal management, etc



***Ascending* Emperor Penguin *approaching* sea water surface close to edge of Antarctic ice shelf. Note highly visible trail of air bubbles. From BBC (2001), with permission.**

ACTIVE FLOW-FIELD MODIFICATION/MANIPULATION BY ENERGY ADDITION/REMOVAL: Examples

- **A BIOMIMETIC EXAMPLE : Flight of the Emperor Penguin. (Drag reduction)**

- **SUPERCAVITATING TORPEDO: (Mach 3 Underwater)**

  - **Operational. Deployed with Russian Navy (2004).** The **Russian Shkval (Tempest)** torpedo is thought to feature a flat disk cavitator at the nose to create a partial cavity that is expanded into a supercavity by gases injected from forward mounted vents. Small starter rockets get the weapon moving until a cavity is formed, whereupon the large central rocket kicks in.

- **MITSUBISHI CARGO SHIPS.**

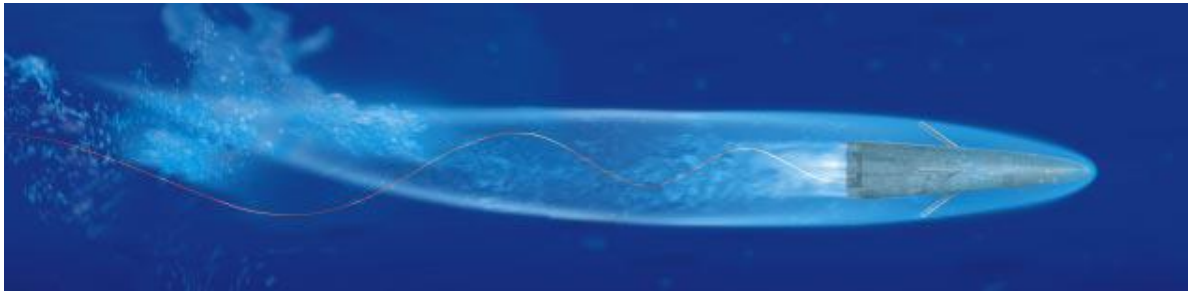
- **RUSSIAN AJAX HYPERSONIC VEHICLE (Plasma/MHD Energy Bypass Concept)**

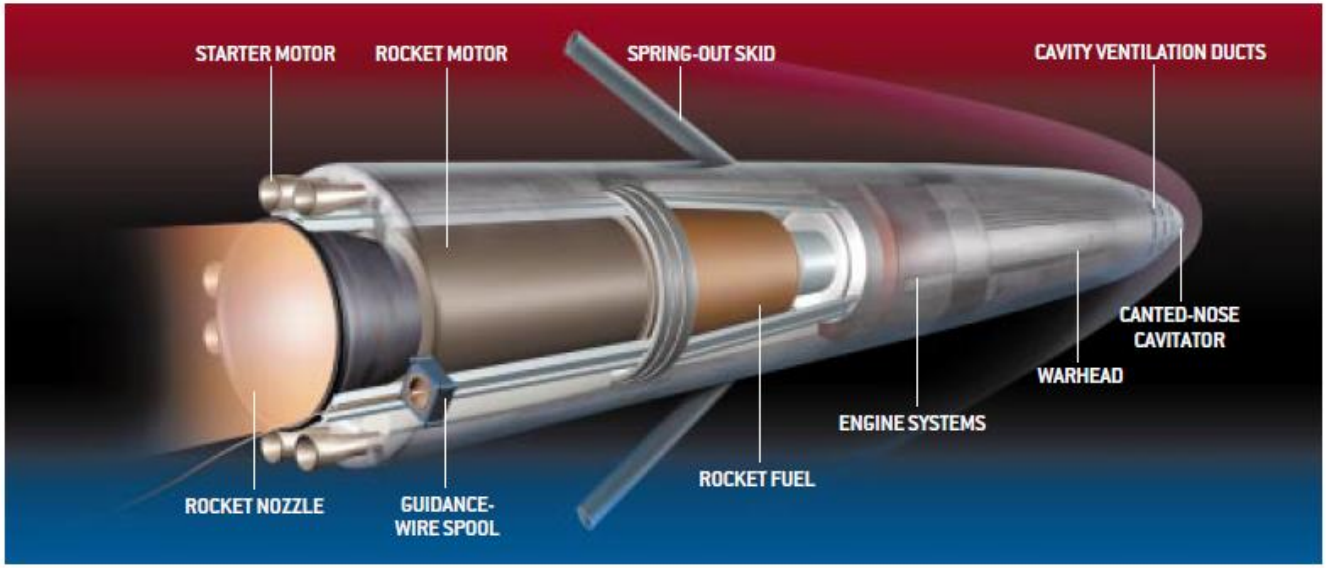
  - **Modify the Flowfield the Vehicle Flies in.**

- **SONIC BOOM MITIGATION/REDUCTION: Our nontraditional aproach**

- **ANTI-RADAR CLOAKING**

WARP DRIVE UNDERWATER





CAVITATORS

Russian Navy Shkval (Tempest) Torpedo: **230 MPH** under water!!

Slender axisymmetric bodies, such as the high-speed Russian Shkval (Tempest) torpedo *create long* ellipsoidal super-cavities. The torpedo is believed to have a flat disk cavitator at the nose to create a partial cavity that is expanded into a supercavity by gases injected from forward mounted vents.

Different nose geometries may be used to create supercavities .

Mitsubishi Uses a Sled of Bubbles To Improve Ship Efficiency

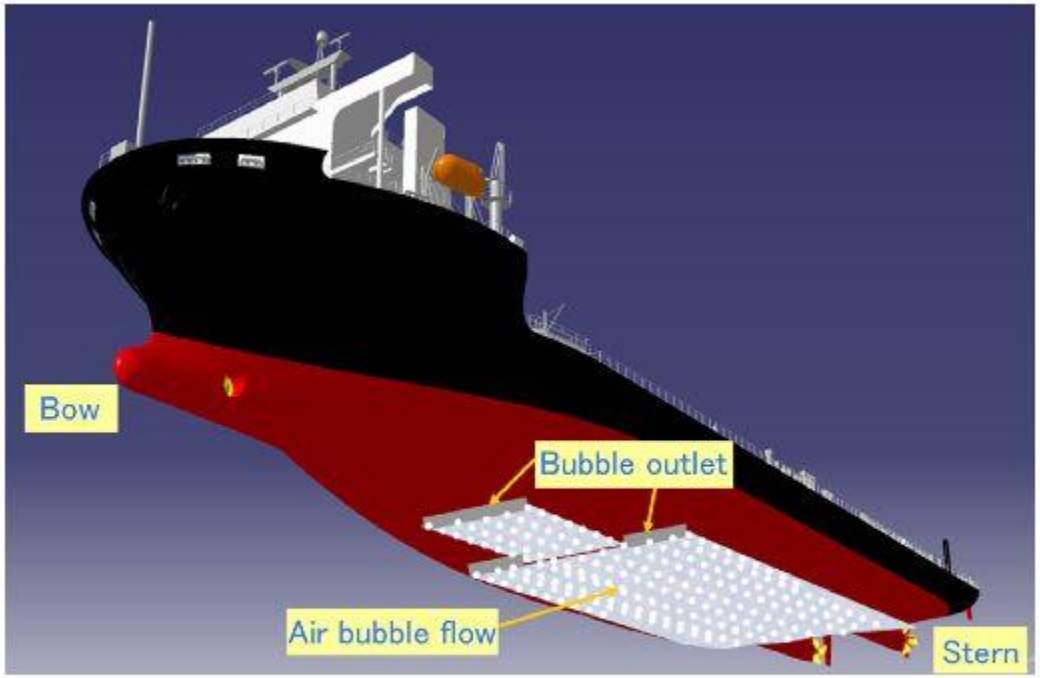


Figure 1 Image of the air lubrication system
The bottom of the ship is covered by air bubbles released from the bubble outlets.

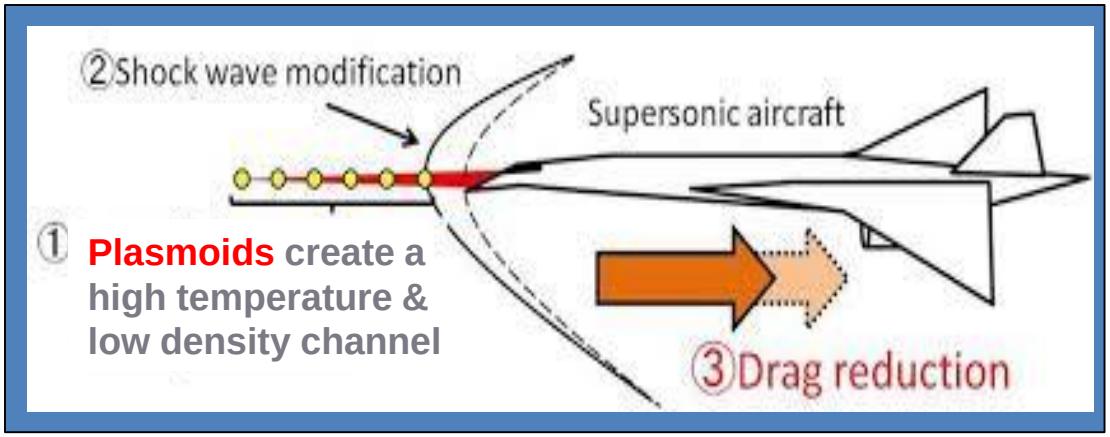
Reducing the frictional drag on the hull of a ship saves fuel and lowers CO2 emissions. To achieve this, MHI developed the Mitsubishi Air Lubrication System (MALS), which reduces frictional drag by introducing air bubbles by air blowers into the water around the bottom of a ship's hull, covering the ship in bubbles. By arranging the air blowhole locations and shape and controlling the air volume, the lubrication effect has been enhanced, reducing CO2 emissions per container transportation by 10 percent.

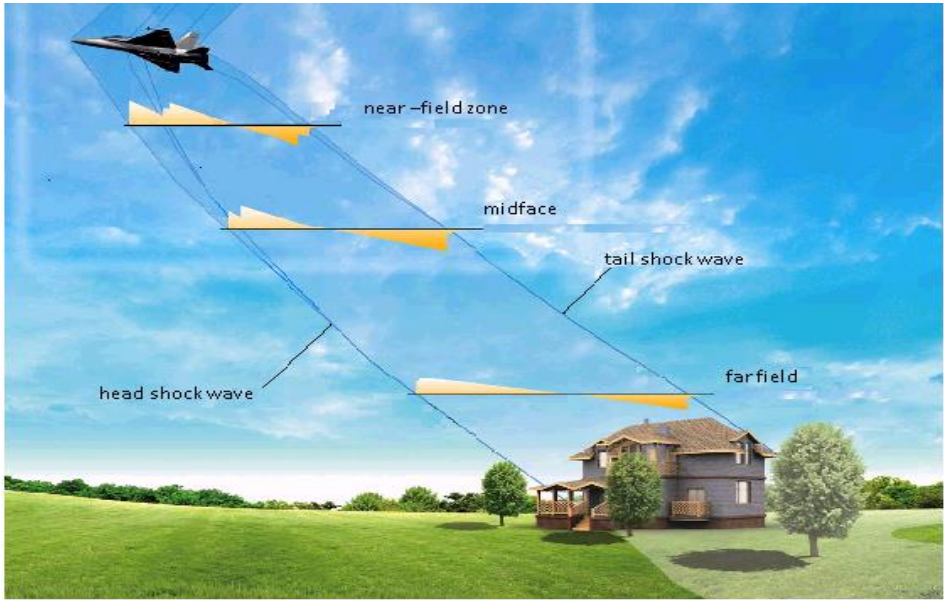
Mitigation of Sonic Boom

by

Forward Pulsed Plasma Energy Deposition

Vehicle shape modification





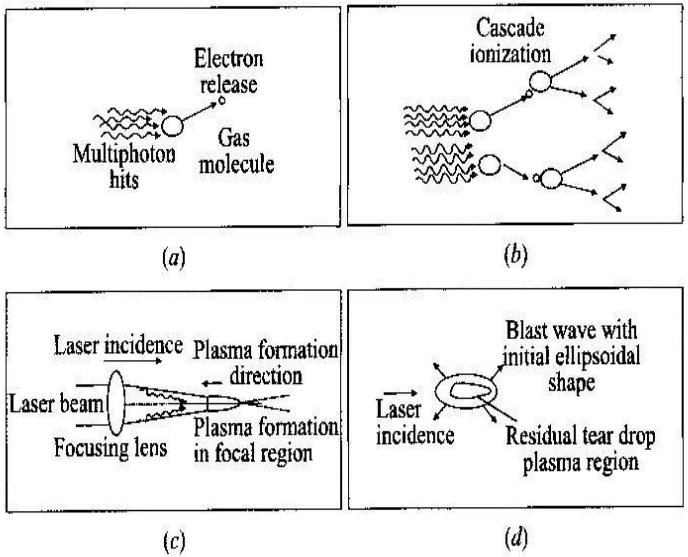
The application of forward energy deposition to sonic boom reduction is NEW!

Also different is that the energy will be deposited far upstream of vehicle.

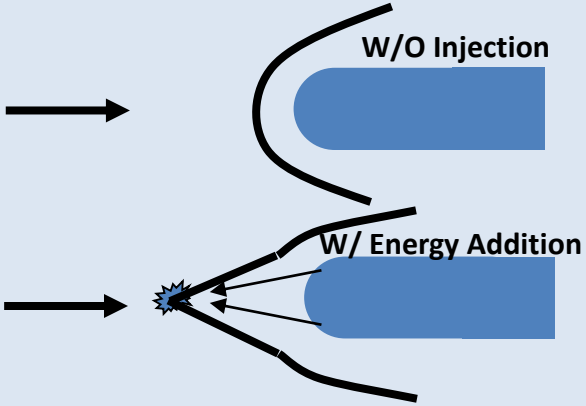
Key challenges are the geometry of the plasma signature, and a practical way to deposit the plasma.

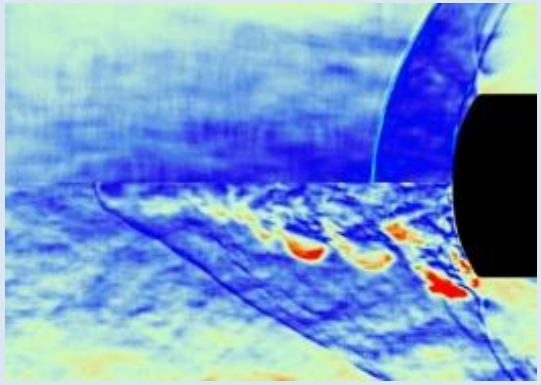
Laser Approach-the physics

- A laser beam strongly focused an be used to ionize and heat gas locally
  - Typical Power Density >10^{12} W/cm^2
- Three basic mechanisms for plasma formation
  - Field ionization
  - Multiphoton ionization
  - Cascade driven ionization
- Laser produced plasma offer a compelling solution to heating or modifying shock structure
  - Energy imparted to electrons non-thermally then couples to neutrals via collisions thus heating the gas (more efficient energy transfer than heating bulk gas)
- To generate filament, laser is tightly focused to achieve high field. Pulse duration is short to force a large number of photons into the tightly focused spot (fs time scales ideal)



Laser-Induced Plasma Application to Flow Control: Wave-Drag Reduction





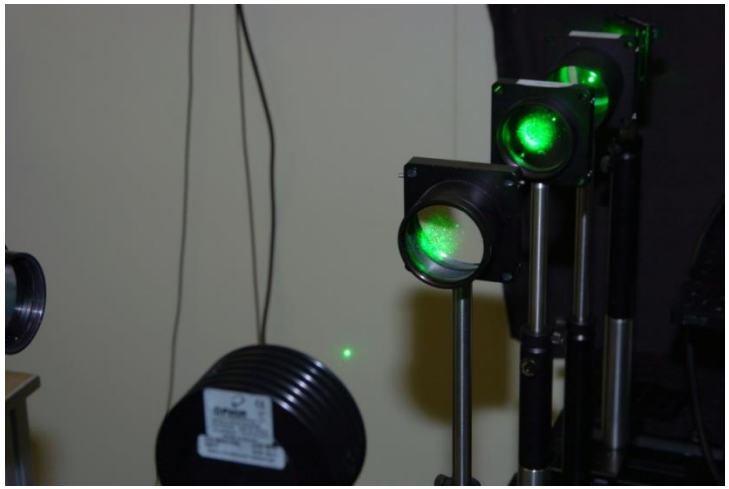
Schlieren images of the shockwave in front of a supersonic missile:

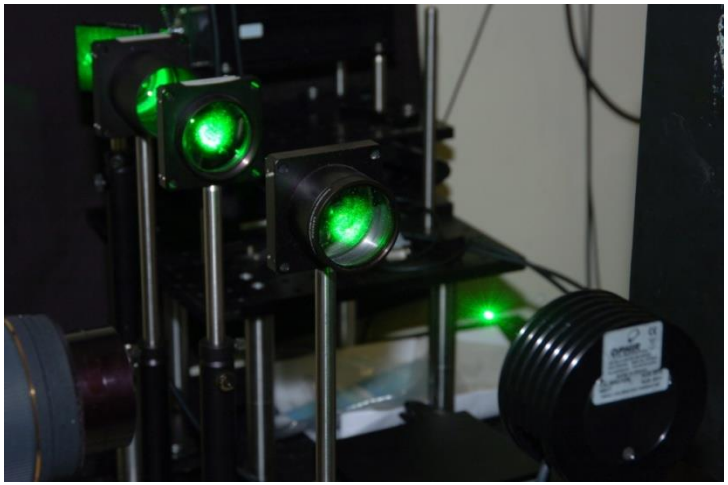
- upper semi-picture -WITHOUT
- lower semi-picture - WITH

laser induced energy deposition.

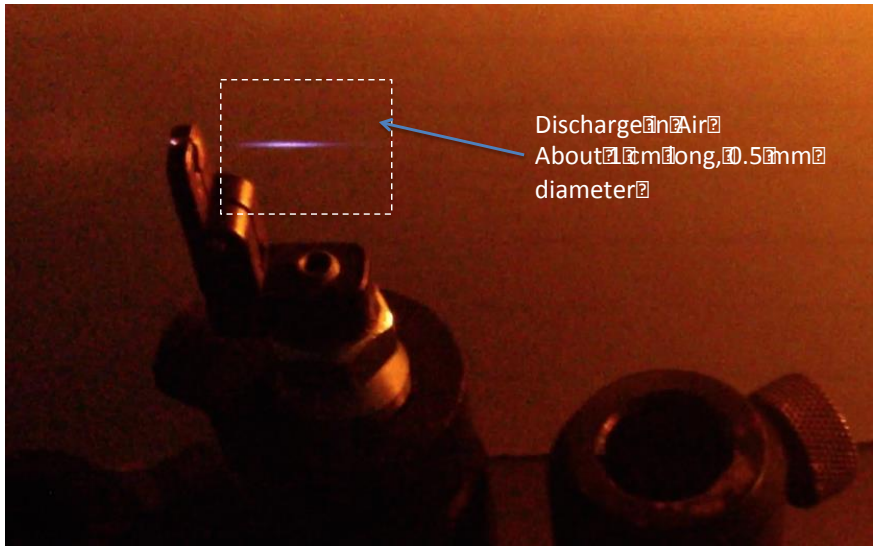
The drag reduction that has been proven by these experimental investigations and numerical modelling is, presumably, caused by local heating of the gas flow

STATUS: LASER-INDUCED PLASMA: RECENT LAB EXPERIMENTS





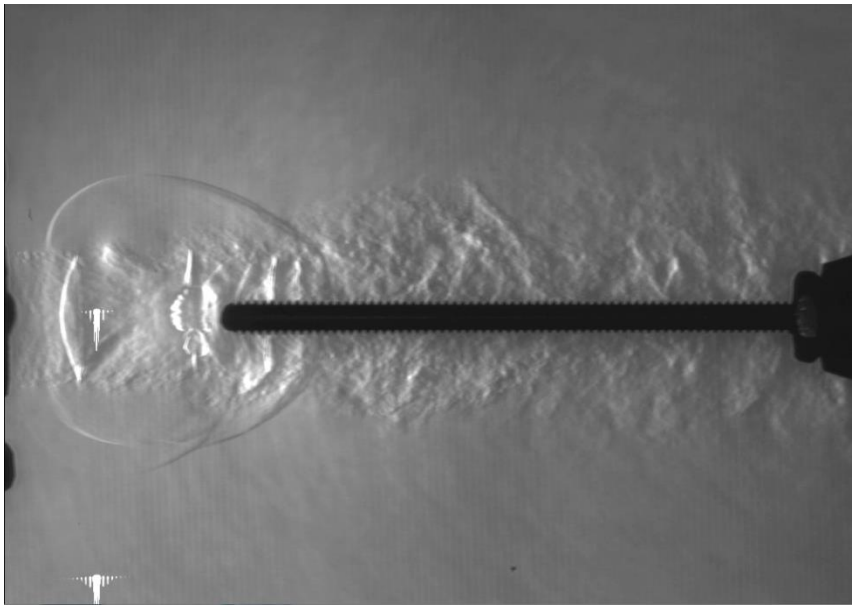
Plasmoids obtained by focusing Nd:YAG Nanosecond pulsed laser beam: 532nm, 5-30mJ, 4-5 nanosecond pulses at 20Hz. Laser has > than 400mJ capability.



Laser filaments were generated by focusing a **Femtosecond Ti-Sapphire laser beam,** 1-12 mJ, 30 fs width, 500 Hz repetition rate.

Filament 1-2 cm long
Filaments produced by field ionization of room air

STATUS: Preliminary Experiments
Interaction of Plasmoid with Bow Shockwave.



Plasmoid was created by focusing a 50 mJ Nd:YAG laser that has a pulse width of 4-5 nanoseconds, and repetition rate of.20HZ.

Photo is taken using a dual pulse Schlieren that records flow phenomena that is highly unsteady. Facility uses shop air and a small convergent nozzle that is designed for Mach 1.6. The model (long black rod) is simply a screw with a blunt nose.

The blast wave (large reverse cardioid shape) is clearly seen. The interaction between the plasmoid and the bow shock at the tip of the rod is clear. Note that, geometrically, this is an extreme case where the blast wave is much larger in size than the model size. Experiments are conducted lab in Bldg 77/318. Nd:Yag laser has up to 420mJ capability. Future experiments to be conducted with model with an ogive nose at 25 mJ pulse energy.

Passive Millimeter Wave Imaging for Aviation Safety and Homeland Security:

SEEING THROUGH FOG

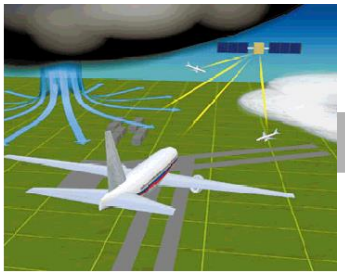
RADIOVISION.

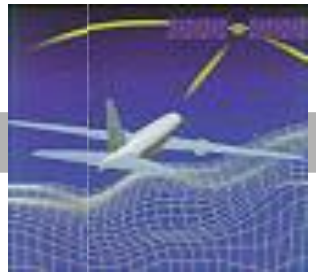
IR Vision

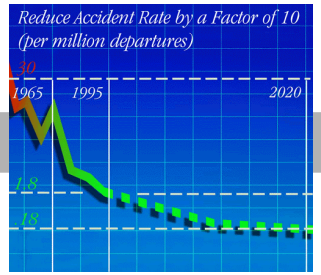
Detection of Hydrometeors

Aeronautics & Space Transportation Technology Strategic Roadmap

***Pillar One*:**
Global Civil Aviation







Safety **2000** *Human-Related Factors* | *Increase Airport Capacity* | *Improve Navigational Aids* **2025** *Reduce Accident Rates 10X*

Millimeter Wave Radiometry at 94 GHz with Super-Resolution

- **Structurally Embeddable**
- **Low Power Applications**
- **Payload Reduction**
- **Compact**

Space Applications

Remote Sensing of Planetary Surfaces

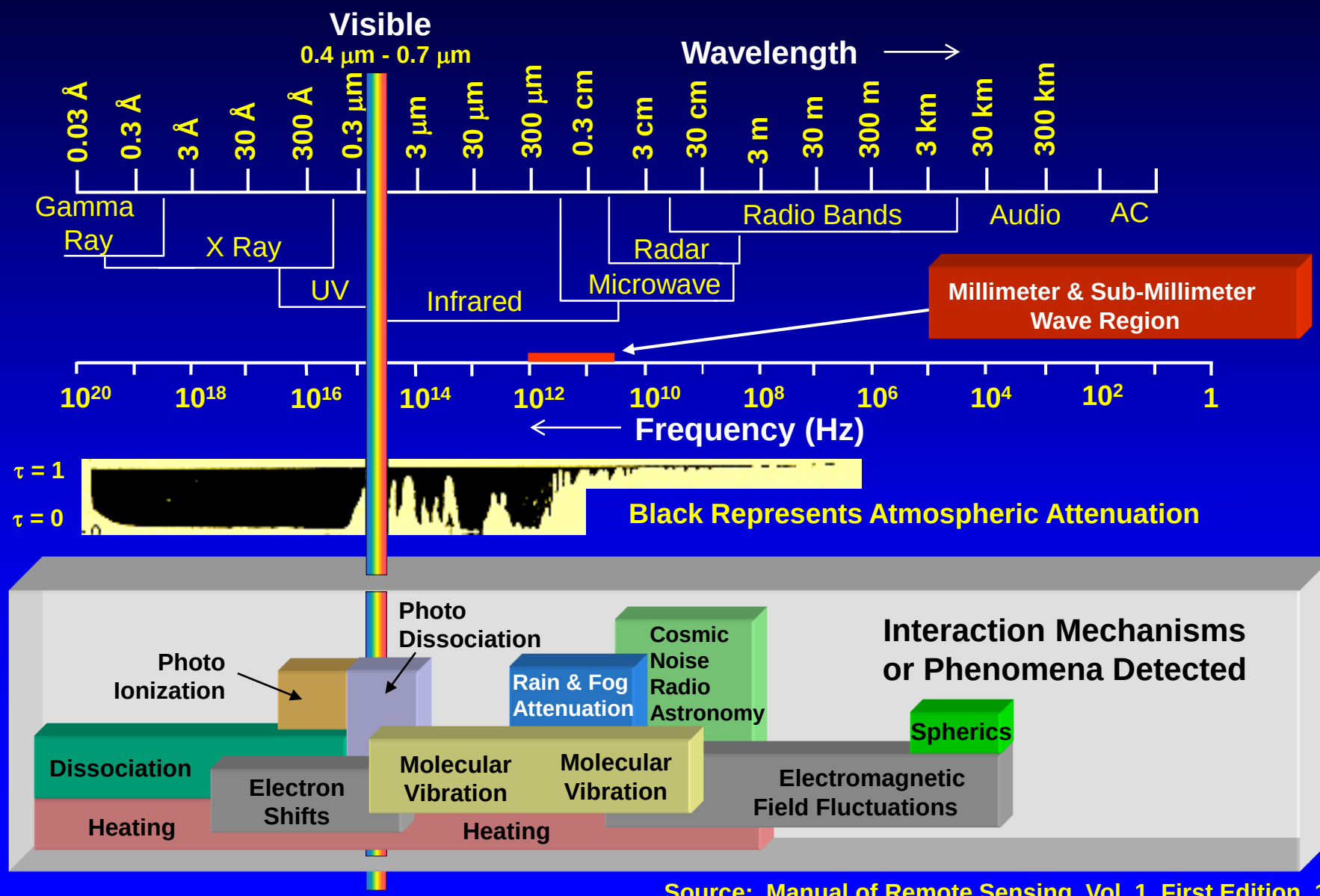
Source: Aeronautics & Space Transportation Technology / Strategic Roadmap, NASA GRC

AIRCRAFT ACCIDENTS: FOG/ BAD WEATHER

- **The worst airplane accident in Aviation History (1977) was caused by fog: Two 747's collided ON THE GROUND in Las Palmas (Canary Islands). KLM 4805 and Pan Am 1736. 583 fatalities.**

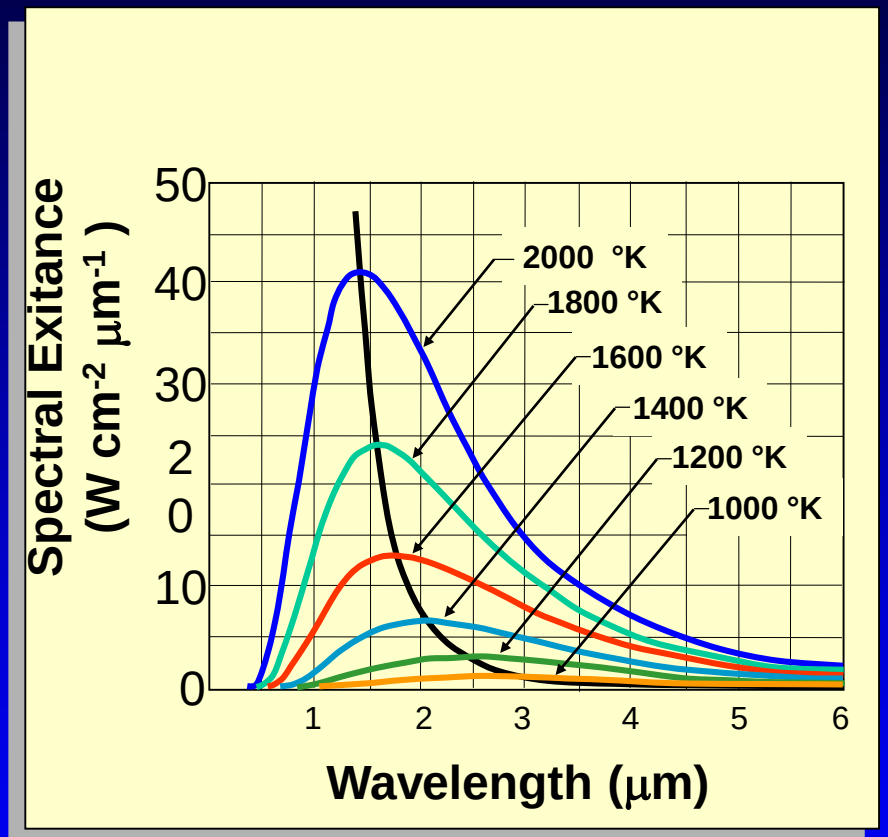
- **2010: Well-publicized accident: Aircraft carrying Polish Premier crashed in thick fog in Smolensk, Russia. Tupolev Tu-154M. 96 casualties.**
- **2010: Tesla Motors Airplane. Struck power lines in fog. Hawthorne, Southern California. Twin-engined Beechcraft. (3 casualties)**
- **2010: Salang Pass, Afghanistan, North of Kabul. Antonov An-24 Turboprop. In heavy fog. 44 casualties.**
- **2010: Boeing 737 – 8HG. Air India Express. Mangalore, India. 158 casualties.**
- **2010: Tripoli, Libya. Afriqiyah Airways. Airbus A330-202. 103 casualties.**
- **2010: Beirut, Lebanon. Ethiopian Airlines. Boeing 737-8AS. 90 casualties. AND ETC ETC……..**

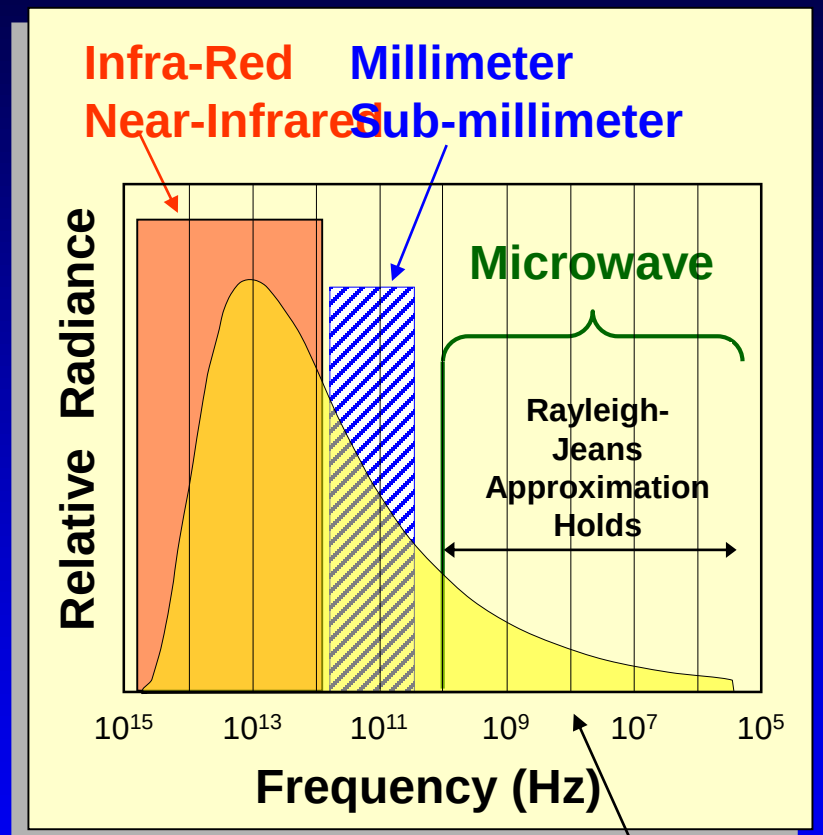
Electromagnetic Spectrum



Source: Manual of Remote Sensing, Vol. 1, First Edition, 1975

Black Body Radiation

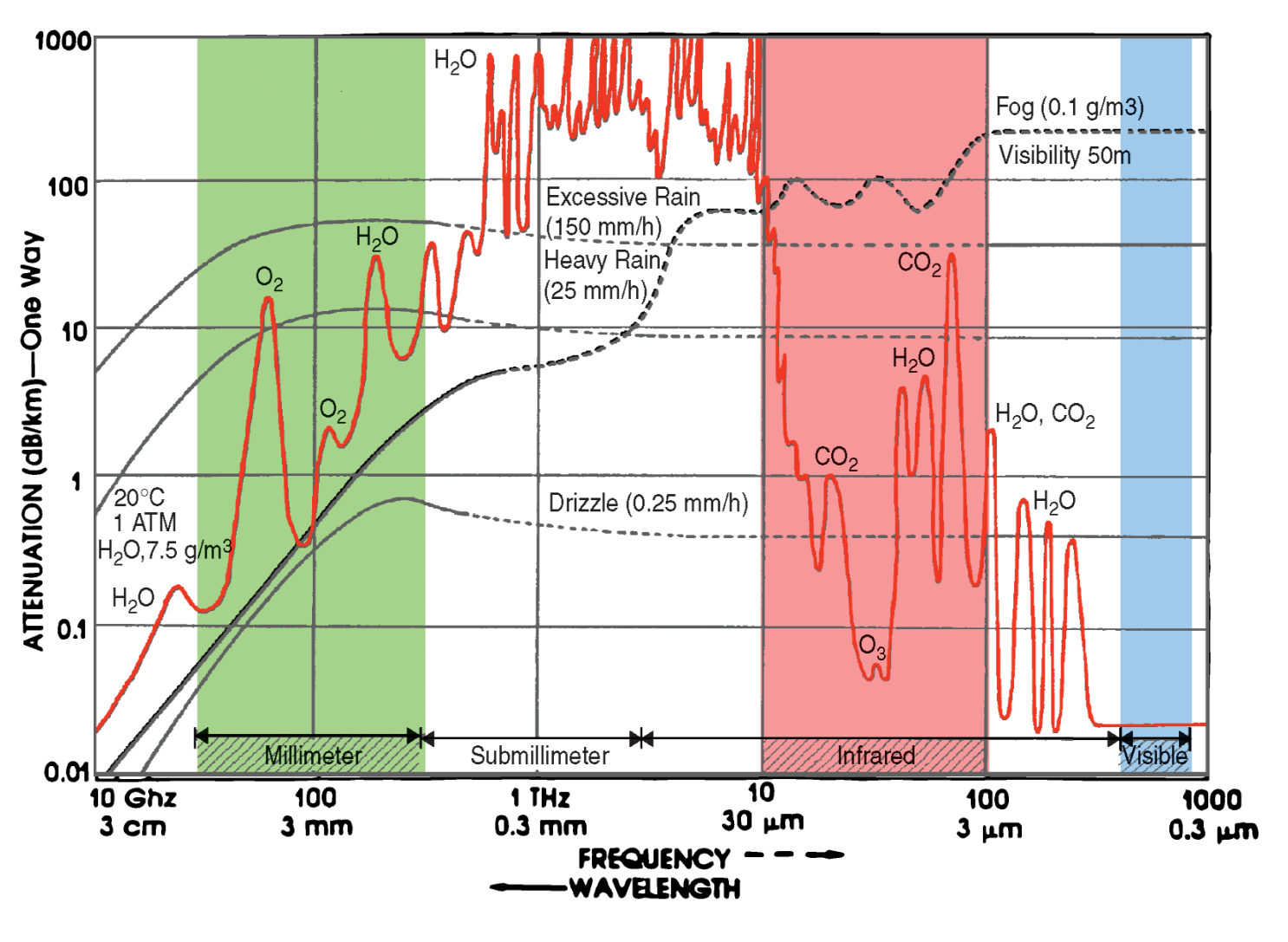




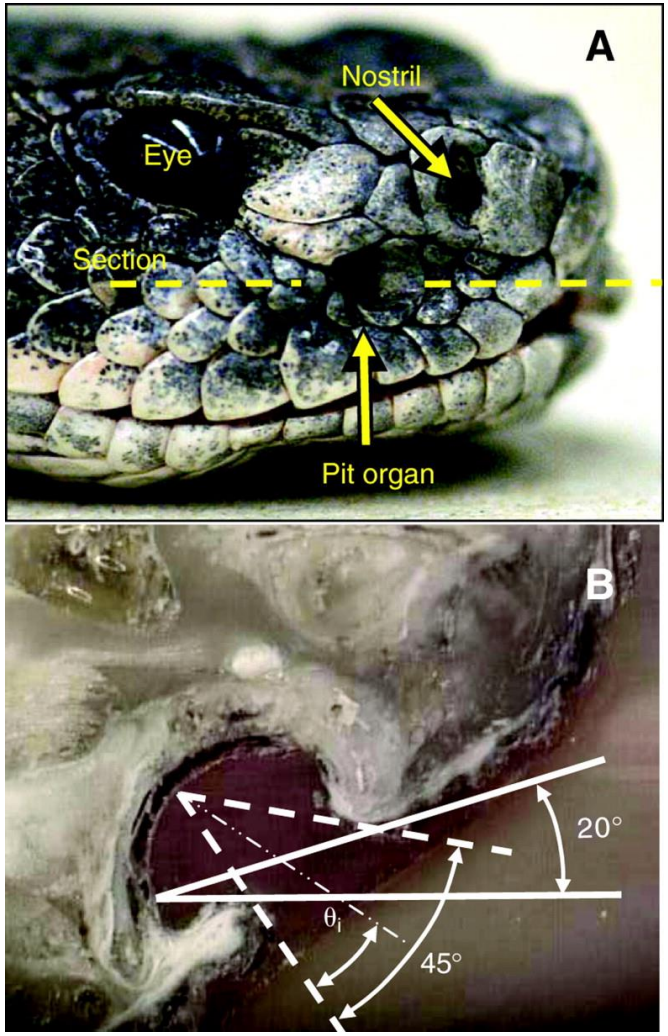
$$B_{bb} = \frac{2 f^2 kT}{c^2} = \frac{2kT}{\lambda^2}$$

Attenuation of Millimeter Waves by Fog, Rain, and Atmospheric Gases

(Researchers have selected 35GHz and 94GHz based on attenuation and resolution)

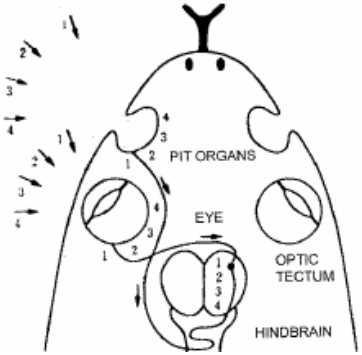


Multisensor Image Fusion: Infrared + Visible
Diamond Back rattlesnake



George S. Bakken, and Aaron R. Krochmal J Exp Biol 2007;210:2801-2810

(A) Close-up view of the head of a western diamondback rattlesnake showing the location of the pit organ.

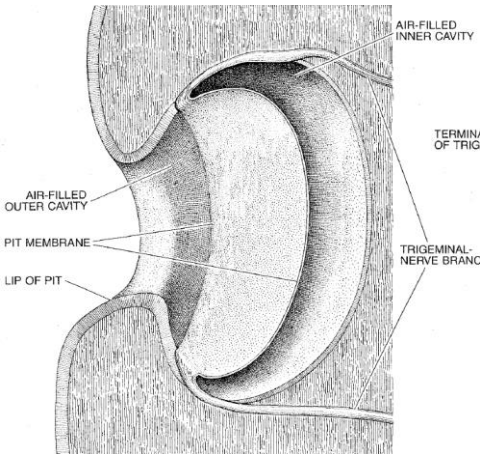


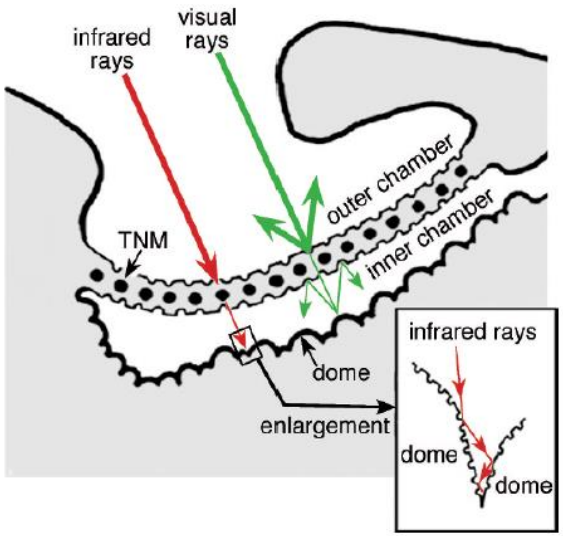
Arrows refer to thermal and visible radiation

Pit vipers, rattlesnakes, boas, pythons possess special organs that form images in the brain of the thermal environment, much like vision occurs in the human brain. Thus these snakes "see" heat (**infra-red based thermal imaging**), and this amazing fusion system is the **most sensitive infrared detector on Earth, natural or artificial.**

Studies indicate image-formation and depth perception are done by the pit organs. IR is merged with visual signals for complete vision. Fortunately fog attenuates IR, so these snakes can't see through fog.

The Journal of Experimental Biology





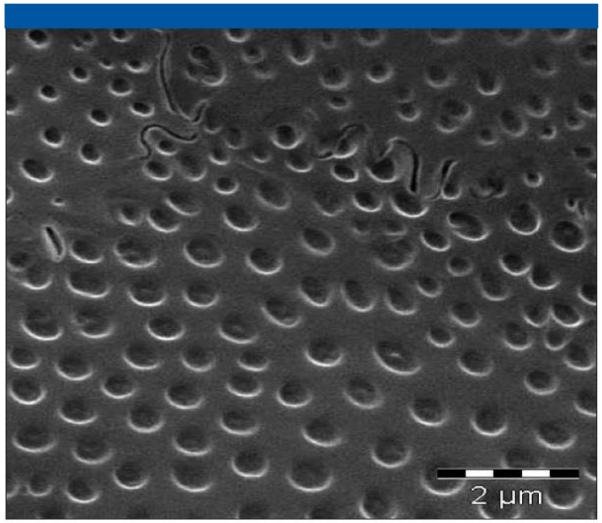


Figure 3: A scanning electron micrograph showing nanopits covering the epidermal surface of the pit organ of the pit viper *Crotalus horridus*. Photo by A.B. Safer.

Pit Organ and surface architecture

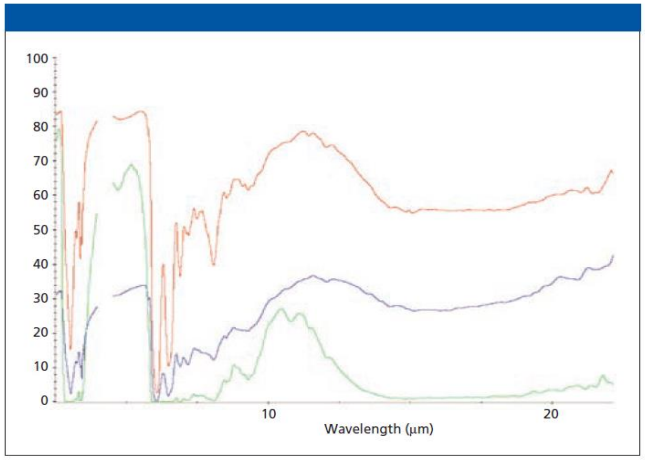


Figure 4: Percent transmission (2.5 µm–25 µm) of various regions of snake epidermis from the pit viper *Crotalus adamanteus*. (red = pit organ epidermis; blue = epidermis from between dorsal scales; green = spectacle).

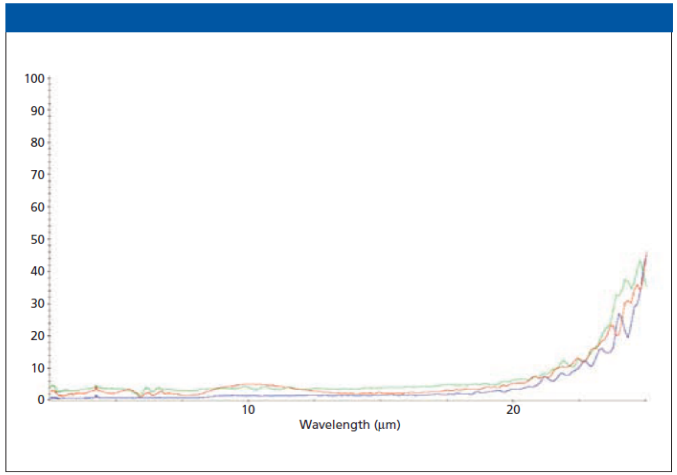


Figure 5: Percent reflectance (2.5 µm – 25 µm) of epidermis from the pit viper *Crotalus adamanteus*. (red = pit organ epidermis; blue = epidermis from between dorsal scales; green = spectacle).

WHAT IS MILLIMETER_WAVE IMAGING (MMWI)

PMMWI is a method of forming images through the passive detection naturally occurring millimeter wave radiation from a scene.

MMWI has the ability to form images by day or night, in clear weather or in low-visibility conditions (fog, clouds, haze, sandstorms) , and even through clothing.

This provides an all-weather capability that allows us to see under conditions that otherwise visible and infra-red sensors cannot do. This is a major advantage of MMW radiation.

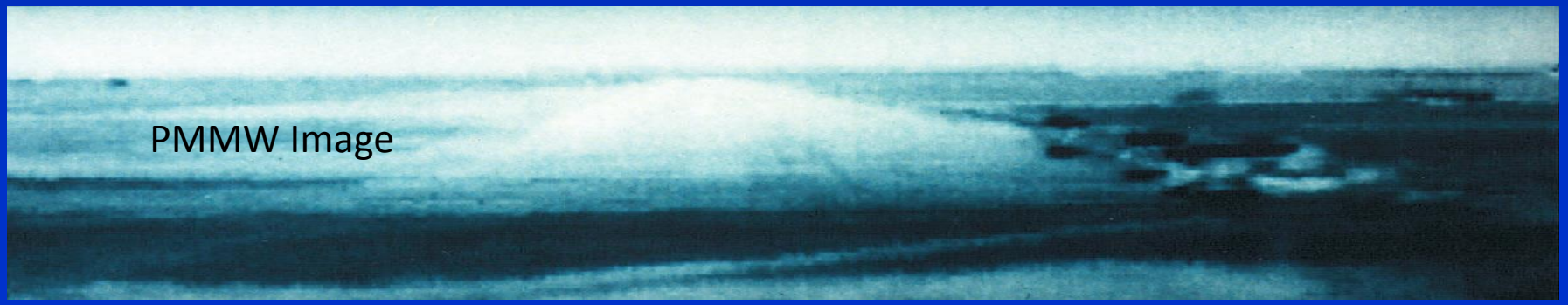
IMPACT: Airports .. Fog could be eliminated as the cause of flight delays.

IMPACT: Security.. Imaging of concealed weapons and other contraband could be accomplished in a non-intrusive manner using MMWI.

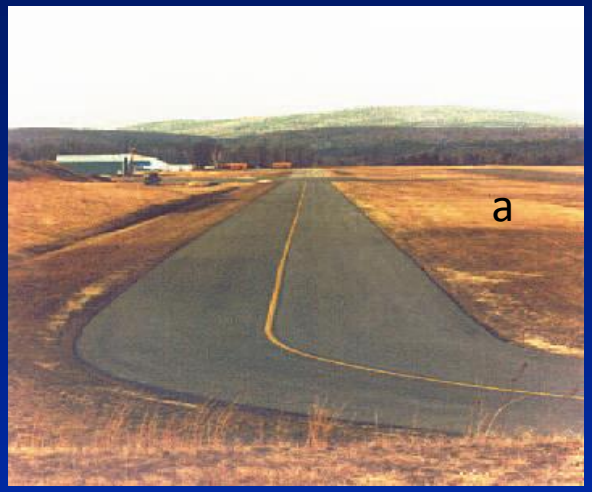
Why Passive Millimeter-Wave Imaging?

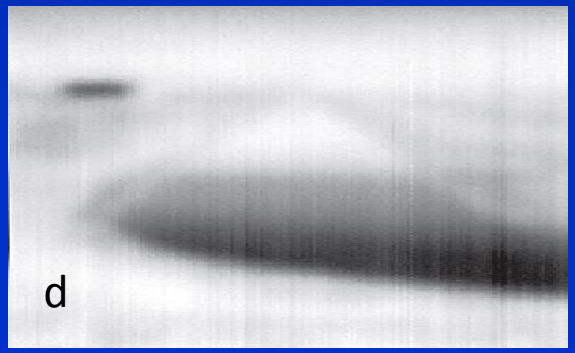
- All natural objects whose temperatures are above absolute zero emit millimeter-wave radiation.
- **Millimeter-waves are much more effective (lower attenuation) than infrared in poor weather conditions such as fog, clouds, snow, dust-storms, and rain. Also, images produced by passive millimeter-waves have natural appearances.**
- The amount of radiation emitted in the millimeter-wave range is 10^8 times smaller than the amount emitted in the infrared range.
- However, current millimeter-wave receivers have at least 10^5 times better noise performance than infrared detectors and the temperature contrast recovers the remaining 10^3.
- This makes millimeter-wave imaging comparable in performance with current infrared systems.
- **Electromagnetic radiation windows occur at 35 GHz, 94 GHz, 140 GHz, and 220 GHz.**
- **Choice of frequency depends on specific application**

PMMW Images of a runway viewed from the glide slope before touchdown



Airport scene in visible light (a) with varying aperture sizes for a 94-GHz PMMW scanning system: (b) 48,(c) 24, and (d) 12 in.





DESIGN CHALLENGE: FEDERAL EXPRESS

Construct a PMMW imaging sensor that has such a high frequency that the sensor is small enough to fit within an aircraft platform (radome, nose of the aircraft), and yet will provide sufficient resolution to permit safe and accurate navigation, landing/take-off, situational awareness, and other desired functions.

Incorporate the PMMW camera system as a display interface which can be a HUD (head-up) or HDD (head-down).

BENEFITS:

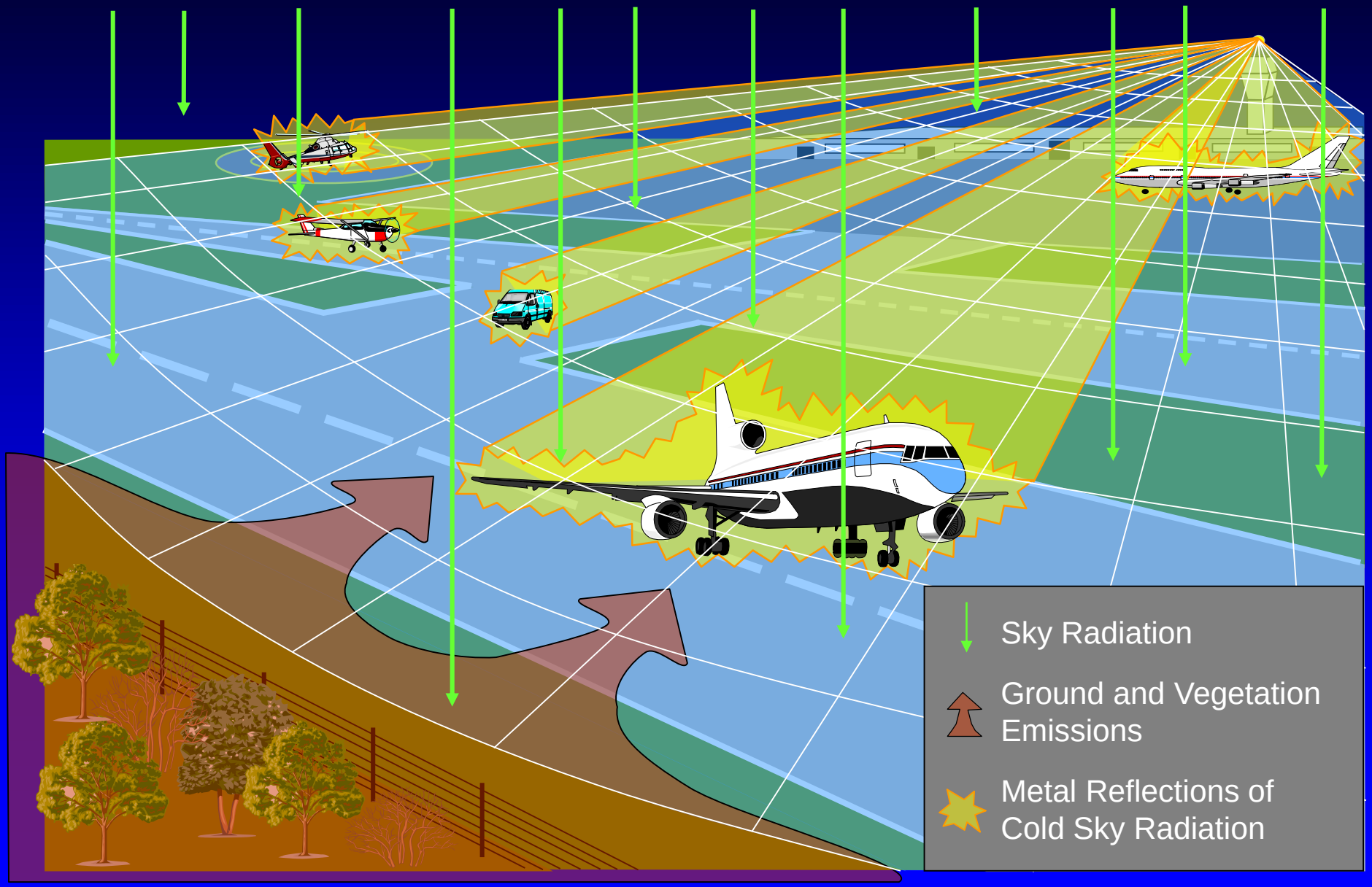
A great navigational utility during final approach.

Good situational awareness during initial approach phase.

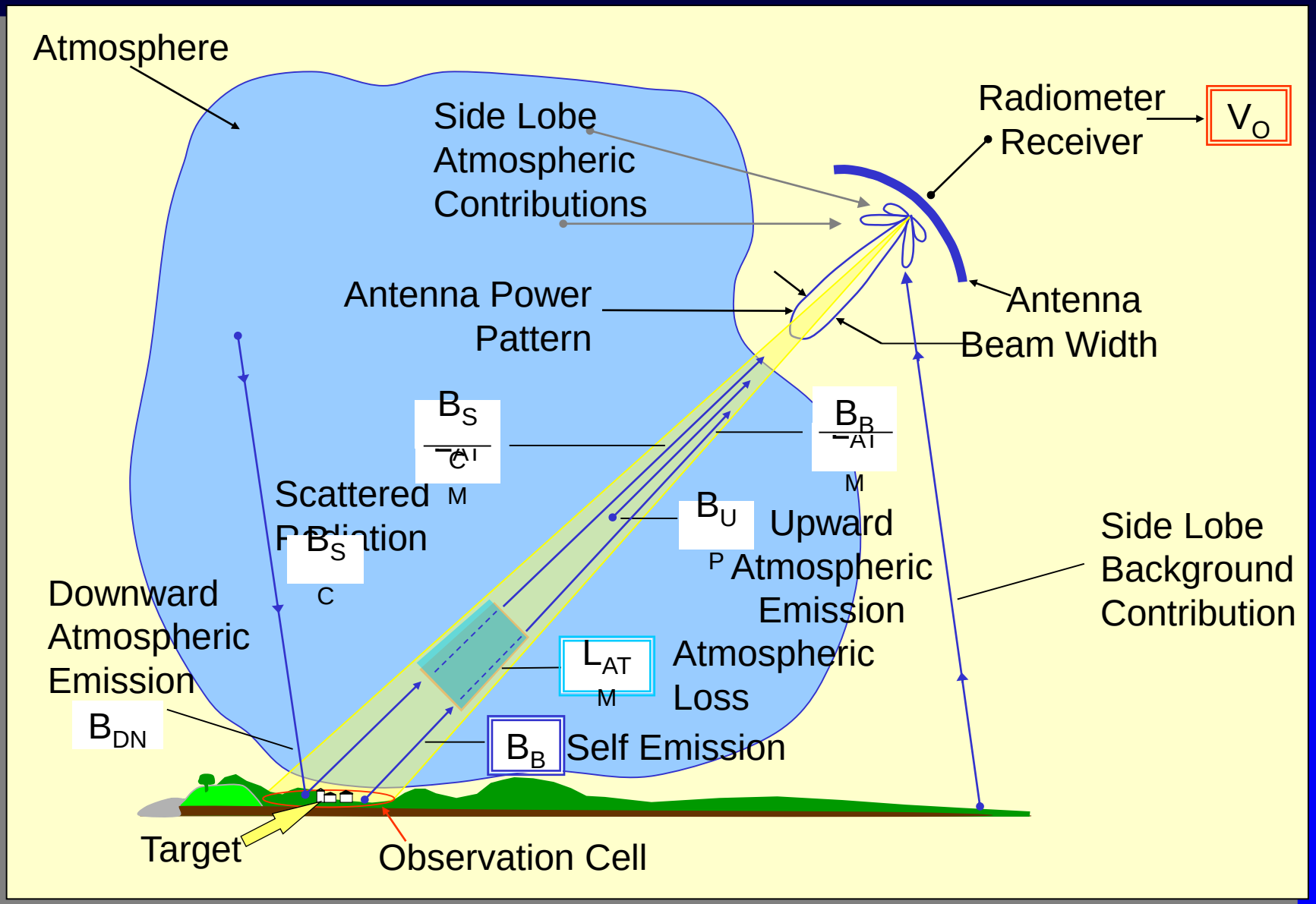
Mitigation of controlled flight into terrain (CFIT).

On-time delivery of packages!! (FeDeX)

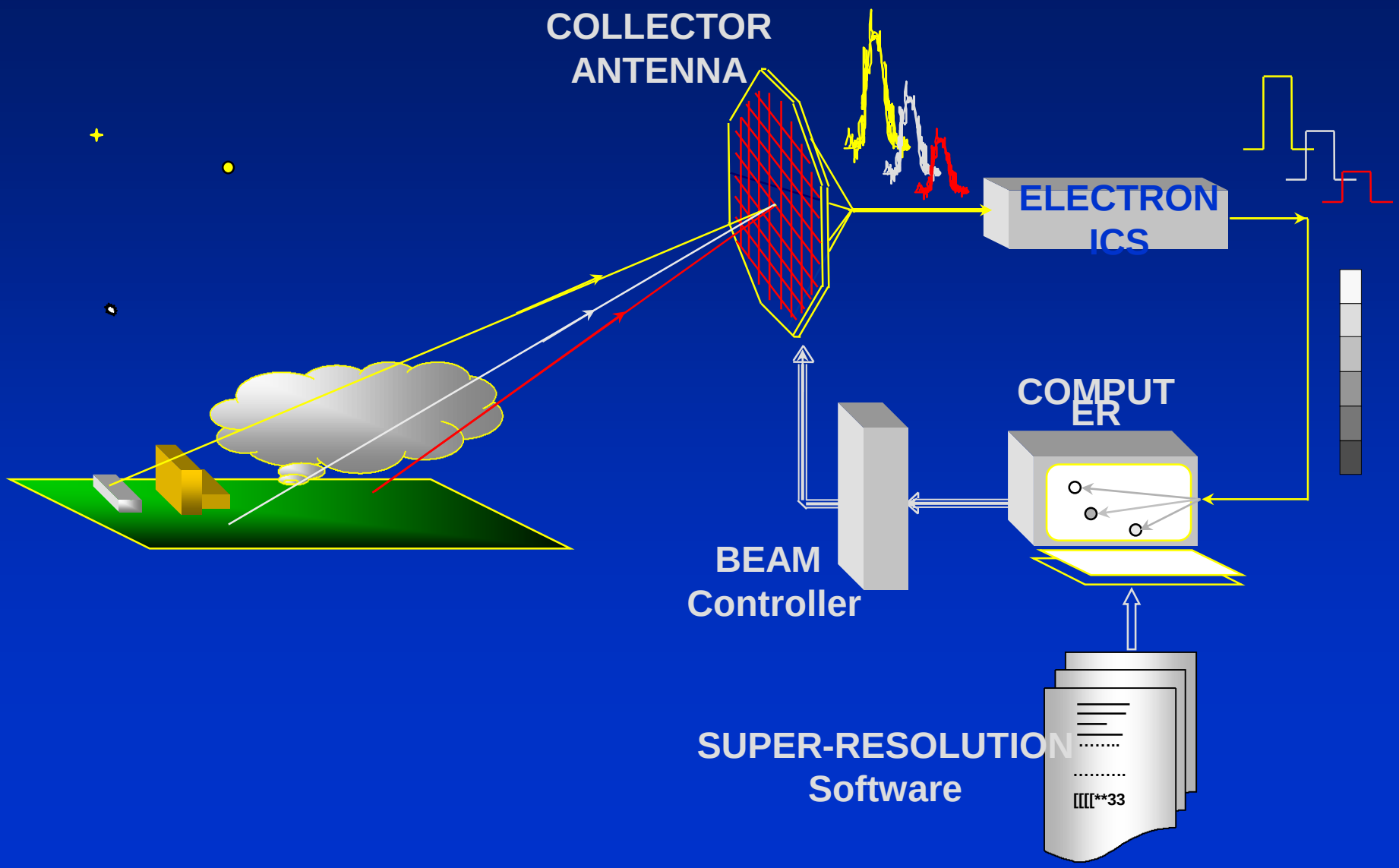
Aviation Safety Application



Passive Radiometric Sensing - Concept



Passive Millimeter-Wave Imager
Concept



JCSU/GRC PASSIVE MILLIMETER-WAVE IMAGING (PMMWI) PROJECT: OBJECTIVES & GOALS

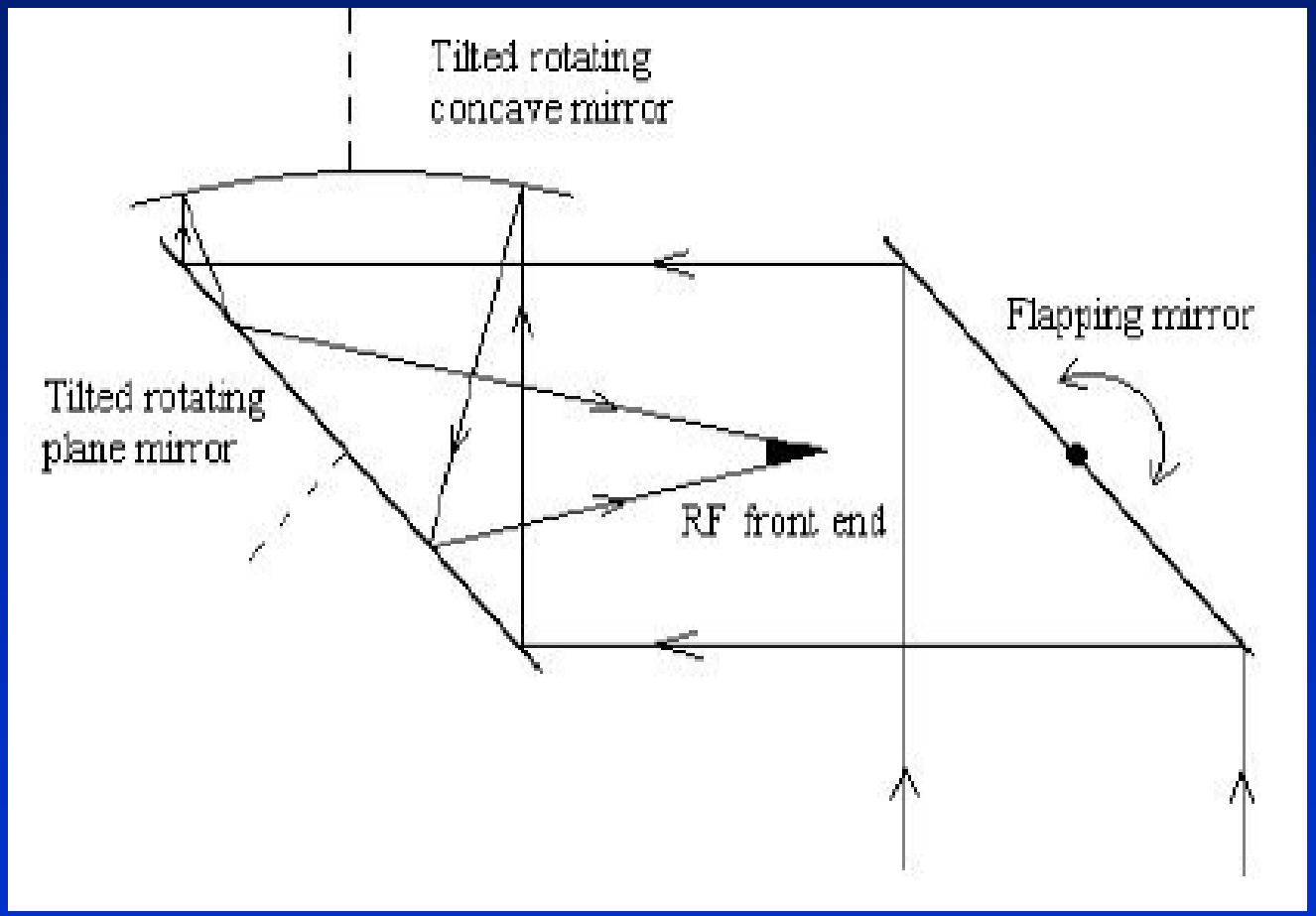
- **Explore the potential application of Radiometric sensors to alleviate atmospheric hazards to aviation, homeland security, and space exploration.**

- **Outline some systems engineering aspects of the design of passive millimeter-wave imaging cameras.**

- **Develop/design an all-weather Radiometer operating at 94 GHz (using opto-mechanical scanning) which employs a Super-Resolution Algorithms for a Real -Time rapid image inversion processing, and is capable of producing very high resolution images (recover scene-spatial frequencies ~or >nX {Rayleigh Limit}).**

- **Construct a functioning system capable of Ground and Airborne Applications: Imaging of Rocket Vehicles through their Exhaust, Detection of Concealed weapons and Suicide Bombers, NDE of Space Shuttle Tile Foam material**

IMAGING ARCHITECTURE of the JCSU/GRC PMMWI



SYSTEM SPECIFICATIONS: JCSU/GRC Passive MMWave Imager

- **RF Frequency Range:87 -99GHz**

- **LNA:Model FLNA-10-18-6 (FARRAN TECHNOLOGY)**

- Gain:18dB min. 86 –100GHz
- Noise Figure:6dB max, 4.5dB typical at 94GHz
- LO Frequency:94.0 GHz within +/-100MHz
- LO Drive:+13dBm typical
- LO Source:Gunn oscillator, GN-10 type, free running, 10MHz/deg.C typical
- Mixer IF Frequency Range:Dc –8GHz minimum
- Mixer Conversion Loss:8dB max, <7.0dB typical
- IF Amplifier Gain:35dB minimum per module, overall 70dB min.
- IF Noise Figure:<1.5dB first module
- Detector:10MHz to 12.4GHz 0.5mV/mico W zero biased Schottky Diode
- Overall System Noise Figure:<6.20dB
- Overall Gain:>50dB

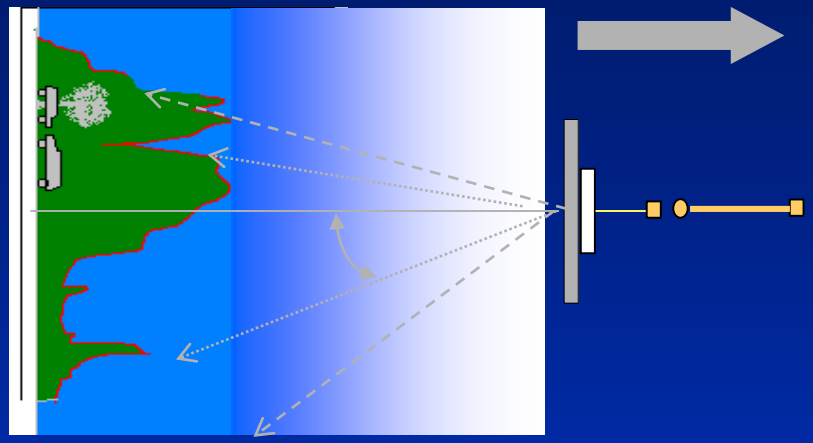
Low-Cost JCSU/GRC Imager: 94GHZ Mechanically-Scanned Radiometer

EXAMPLE OF MILLIMETER-WAVE IMAGE: Concealed Weapon

(JCSU Campus Patrol Officer)

“True” Scene..Recovery_Superresolution Algorithm

Direct Measurement Result



GOAL: Best true “Scene “ R e c o v e r y

INVERSE Problem Solution

EMR-Properties of Propagation media

Mathematical Processing of Measured Data

TIKHONOV - PYTIEV Regularization

$$f = (A^* R^{-1} R^{-1} A + \gamma I) A^* R^{-1} R^{-1} g$$

TRUE Scene

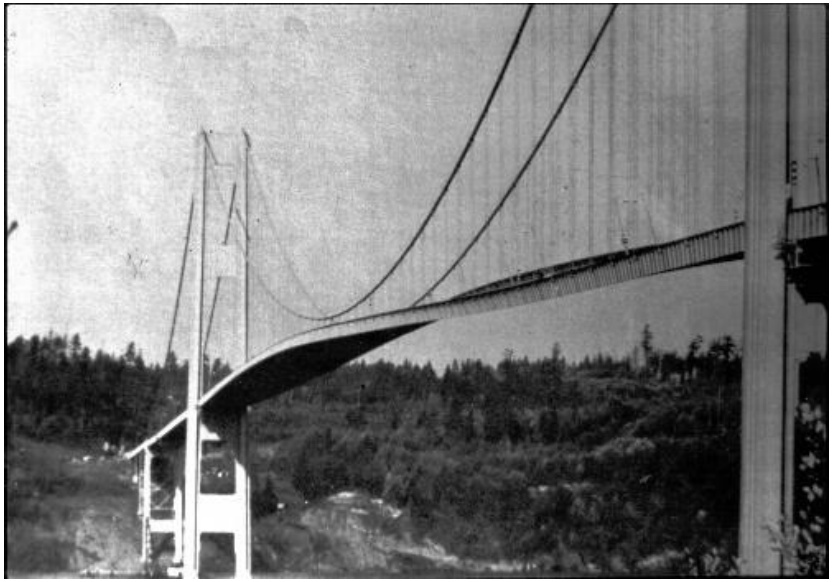
WIND-INDUCED/VORTEX-INDUCED VIBRATIONS:

THE SAGUARO CACTUS

Vortex shedding phenomena occurs in nature. The Saguaro cactus is a typical example. Its distinctive trunk shape enables it to withstand high-speed winds despite it's very shallow root system. The longitudinal grooves significantly reduce the drag and lift forces acting on the cactus, thus providing an advantage during sandstorms. The specific grooved geometry also gives rise to aeroacoustic advantages that are under study.

Suppression of Vortex –Induced Vibrations USNAVY Hydrophones (MSc Thesis)

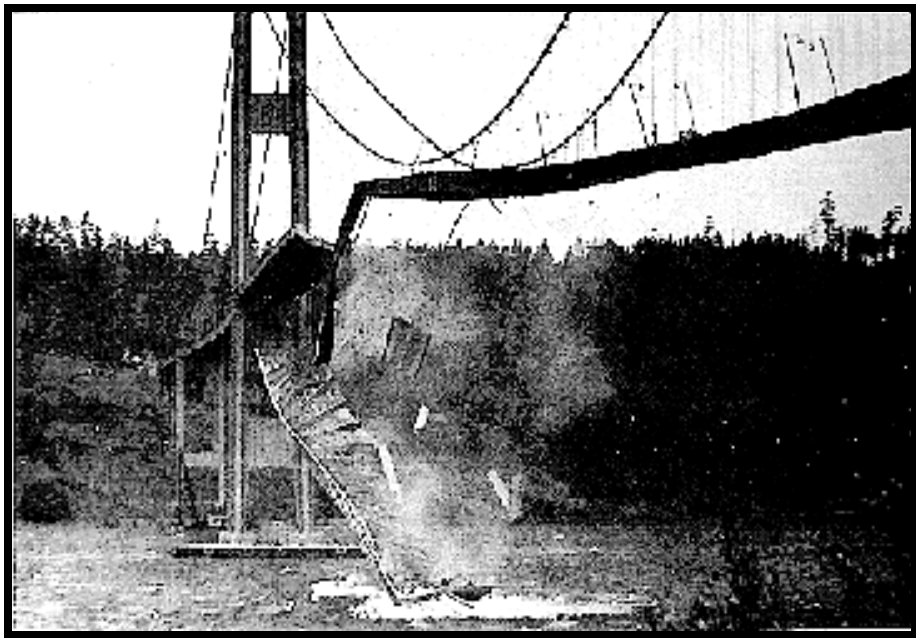
(Searching for mines, holding buoys in position, transmitting and receiving signals, maintaining acoustic hardware in a specified configuration, etc)



Wind-Induced Vibrations: A Design Engineer's Nightmare

Classic Wind-Induced-Vibration Catastrophe (wake-induced flutter from torsional and lateral oscillations?)
Tacoma Narrows Bridge: WA, 1940

The amplitude grew to as much as 14 feet.



Wake Instability

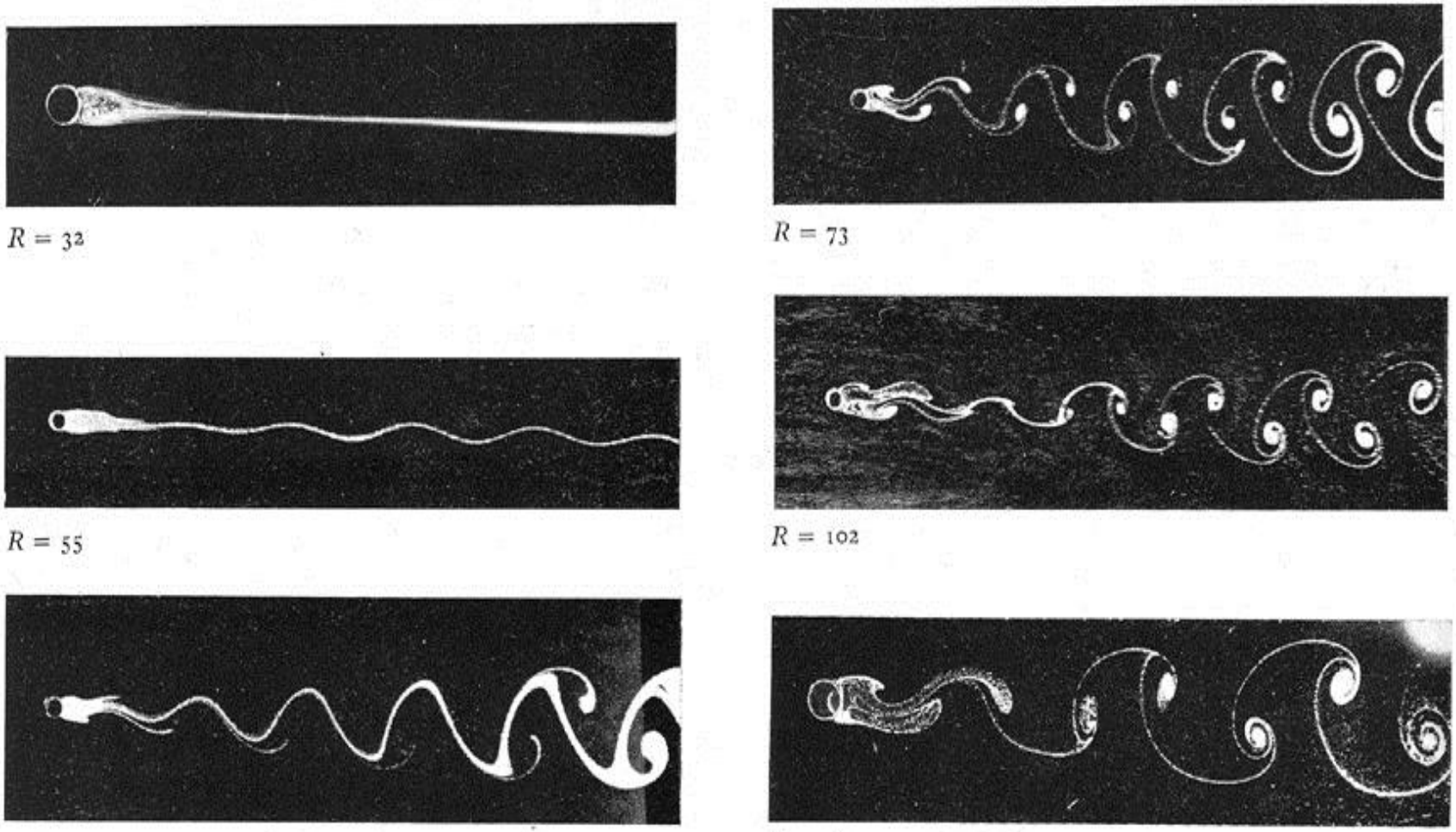
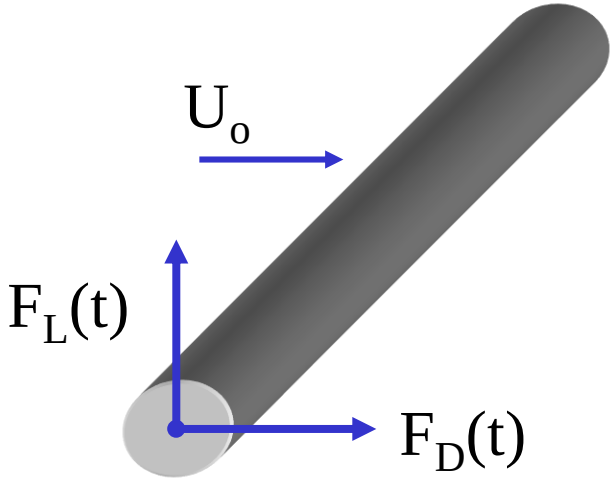


Figure 4.12.6. Streak lines in the wake behind a circular cylinder in a stream of oil. (From Homann 1936*a*.)

Vortex Shedding Generates forces on Cylinder

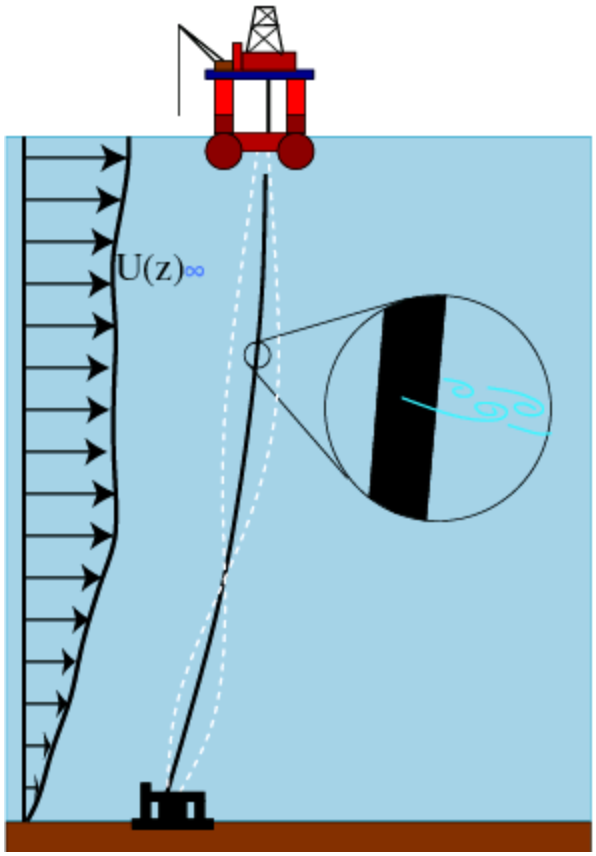


Both Lift and Drag forces persist on a cylinder in cross flow. Lift is perpendicular to the inflow velocity and drag is parallel.

Due to the alternating vortex wake ("Karman street") the oscillations in lift force occur at the vortex shedding frequency and oscillations in drag force occur at *twice* the vortex shedding frequency.

Alternate Vortex shedding causes oscillatory forces which induce structural vibrations

Vortex-induced-vibration in the Ocean: US Navy Hydrophones "Cable Strumming"



- Non-uniform currents affect the spanwise vortex shedding on a **cable** or **riser**.
- The frequency of shedding can be different along length.
- This leads to "cells" of vortex shedding with some length, l_c.
- The hydrophone signal pickup due to strumming is much larger than the signal of interest
- Structural fatigue/damage of cable or riser is a big issue.

Blankson, Isaiah: "Flow-Induced Oscillations of a Flexible Circular Cylinder," MS thesis, Dept. of Aeronautics and Astronautics, Massachusetts Institute of of Technology (1970).

<u>Suppression approach</u>: Disrupt the highly organized spanwise shedding structure in the wake, especially at lock-in. Also a reduced drag is beneficial.

Suppression of VIV/Drag reduction: Saguaro cactus

Vortex-Induced Vibration Suppression

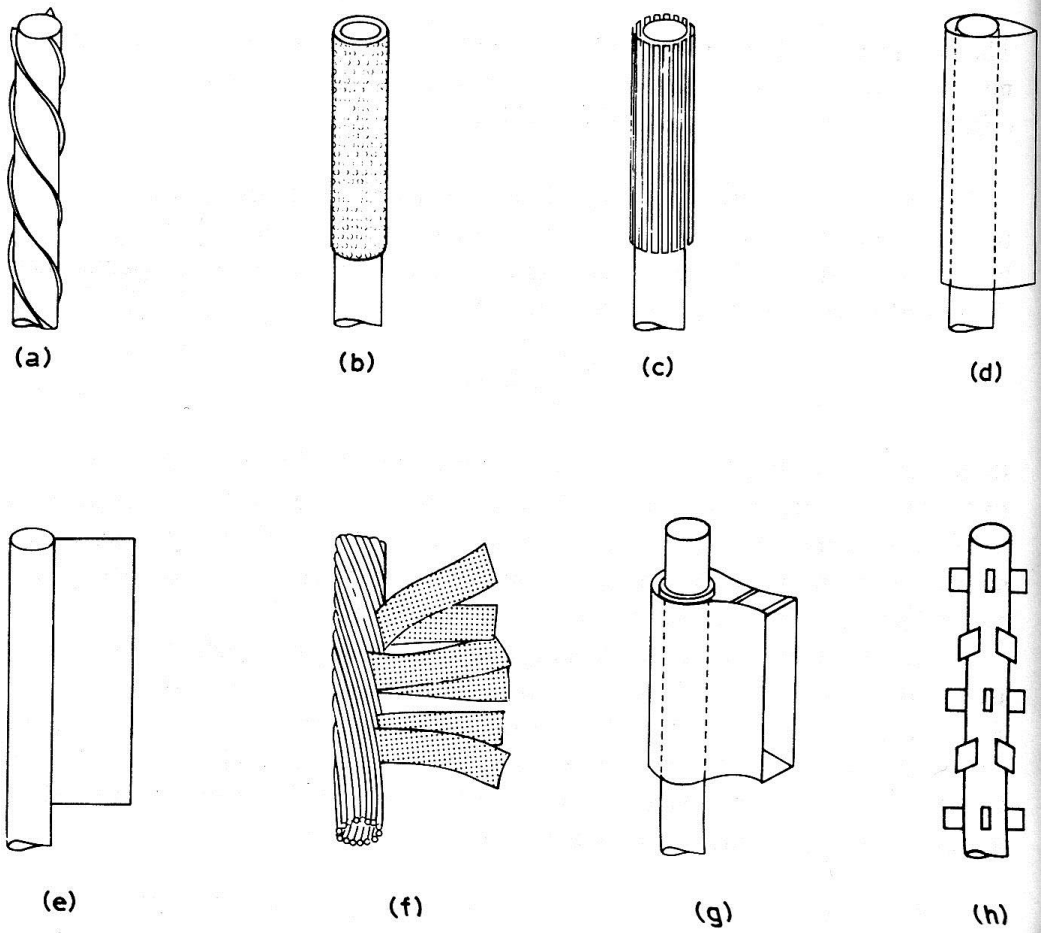
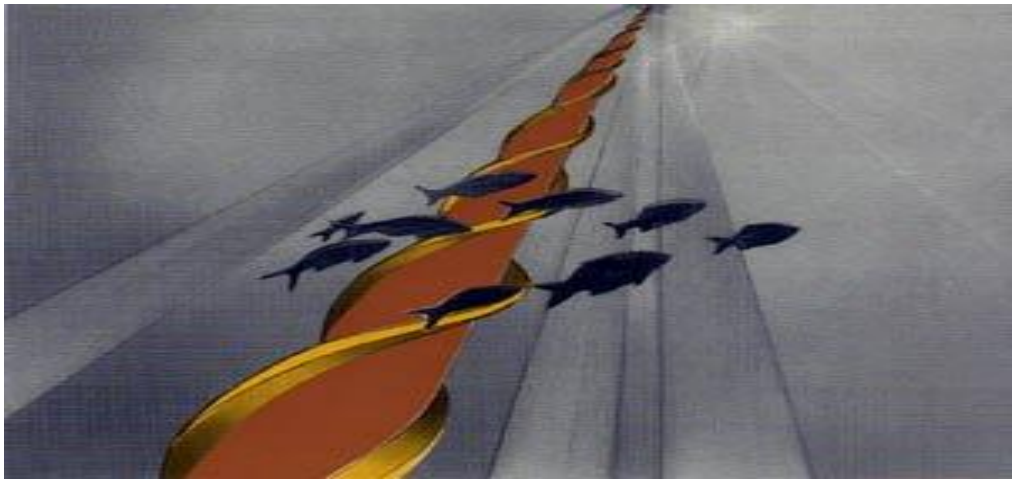


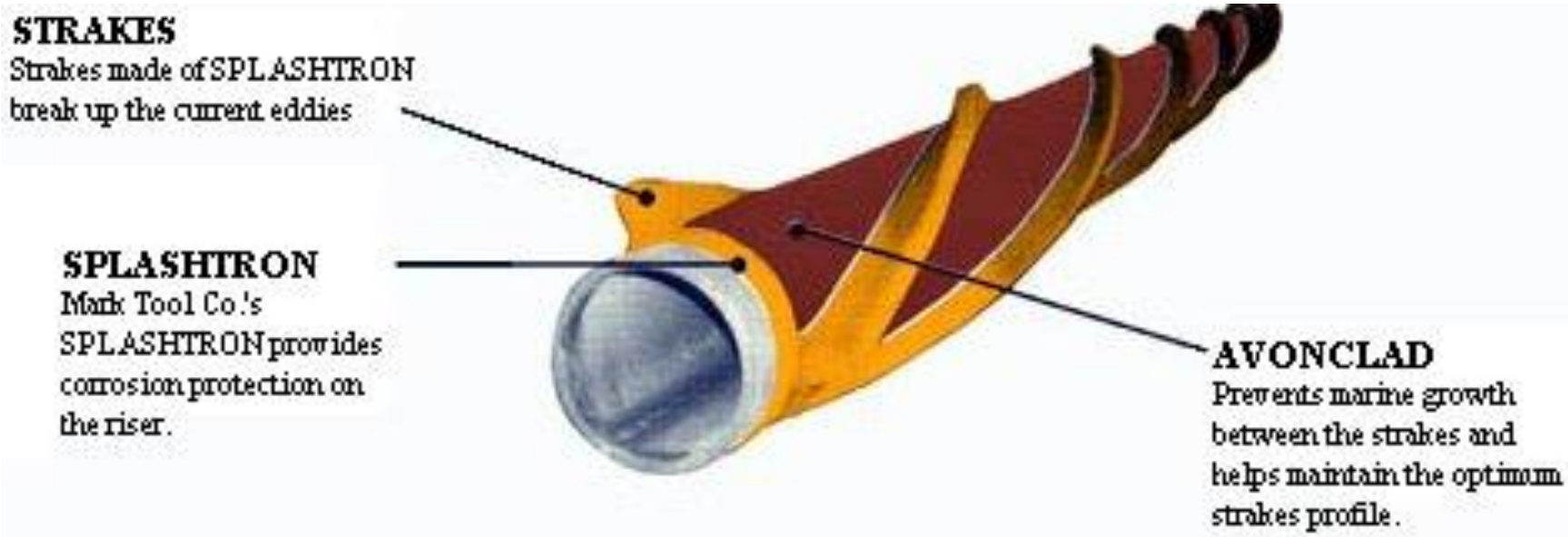
Fig. 3-23 Add-on devices for suppression of vortex-induced vibration of cylinders: (a) helical strake; (b) shroud; (c) axial slats; (d) streamlined fairing; (e) splitter; (f) ribboned cable; (g) pivoted guiding vane; (h) spoiler plates.

- **Helical strake (a)**
- **Shroud (b)**
- **Axial slats (c)**
- **Streamlined fairing (d)**
- **Splitter plate (e)**
- **Ribboned cable (f)**
- **Pivoted guiding vane(g)**
- **Spoiler plates (h)**

Suppression by Helical Strakes



Helical strakes are a common VIV suppresion device.



OPPORTUNITIES FOR RESEARCH:

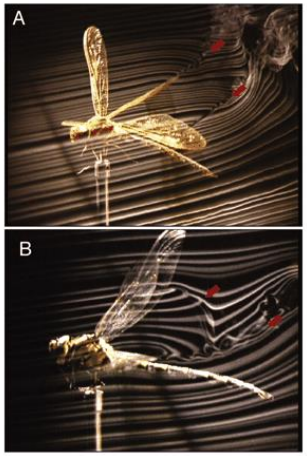
(I)

Opportunities for Expanding the Range of Aeronautical Inquiry

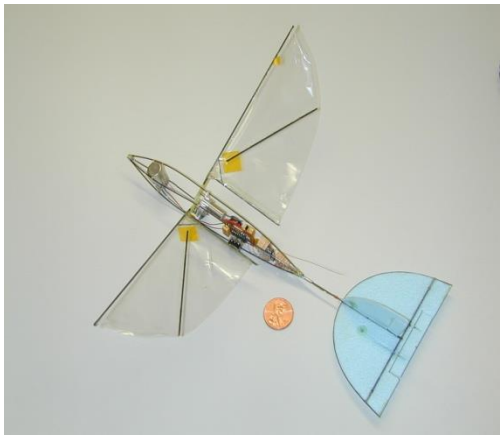

Extremes in Variable Geometry Wings

Formation Flight

Solar Powered Flight



Unsteady Aerodynamics



Micro Air Vehicles (µAVs)

Ultra-Quiet Flight

OPPORTUNITIES FOR RESEARCH:

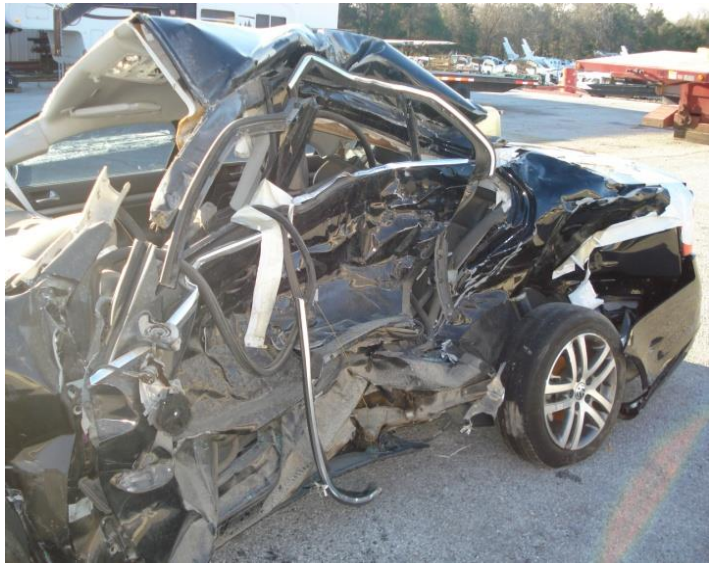
(II)

STRUCTURAL CONCEPTS FOR AUTOMOBILE SAFETY

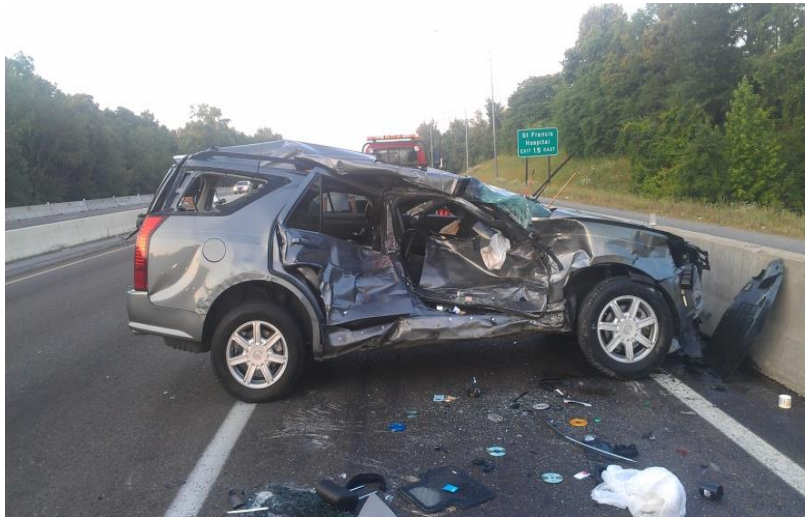
THE WWII WELLINGTON BOMBER (RAF)

Geodetic, Isogrid Structures

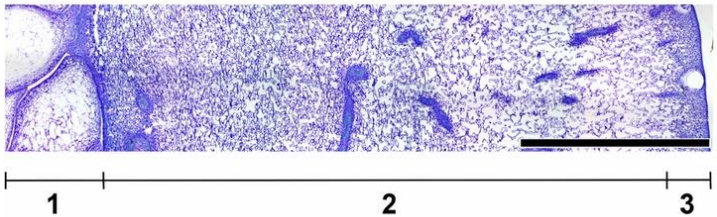
Putting aside the fact that speed kills, and there are reckless drivers, the goal of the automobile structural designer is to protect the contents of a car. There are still a huge number of traffic fatalities. So new structural concepts are desired.

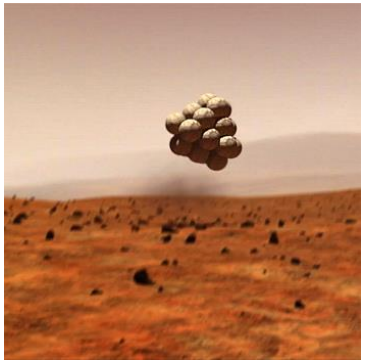



www.WreckedExotics.com



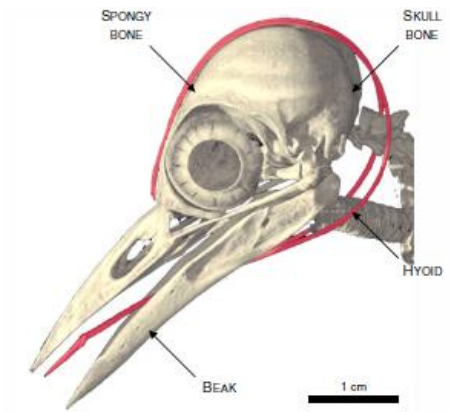
Shock absorption





Structure–function relationship of the foam-like pomelo peel (*Citrus maxima*)—an inspiration for the development of biomimetic damping materials with high energy dissipation
M Thielen, C N Z Schmitt[1], S Eckert, T Speck and R Seidel
doi:10.1088/1748-3182/8/2/025001

Woodpecker's head inspires shock absorbing systems for Humans and Electronics



Woodpecker's head can withstand 1200G's as it drums on a tree at 22Hz.
(up to 25000G's recorded) This is equivalent to stopping in 1 sec from 26000MPH!!

Pilots barely 10G's Max (Blue Angels)

Airplane Flight Recorders about 1000G's

POTENTIAL APPLICATIONS:
Shock absorbers. Impact resistance. Flight recorder electronics.

Protection of athletes from concussions(football helmets).

Protecting spacecraft from collisions with micrometeorites and space debris.

Formula One Racecar Drivers.

Evolution of Fuselage Design / Structural Concepts

- Decades of incremental refinement of details, yet same basic structural concept

B707 (1958)

B737-800 (1998)

Bombardier Cseries Development (2009)

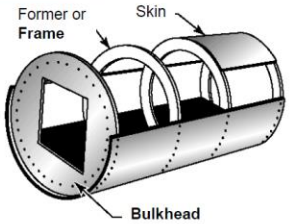
- Composite Fuselage Concepts
  - New materials
  - Fabrication / assembly
  - Different failure modes

A350 Development (2009)

BWB Development, X-48B (2007)

Fuselage Construction

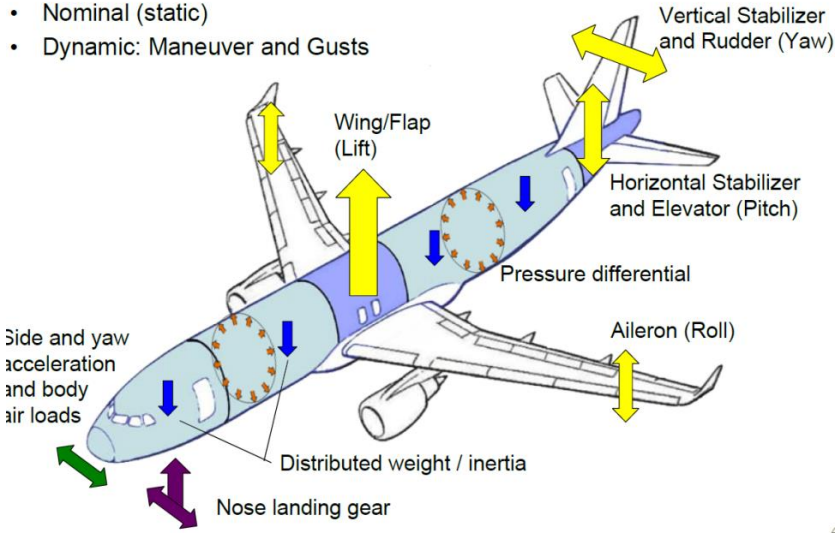
- **Monocoque**, meaning 'single shell' in French, is a construction technique that utilizes the external skin to support some or most of the load (structural skin, stressed skin, unibody)

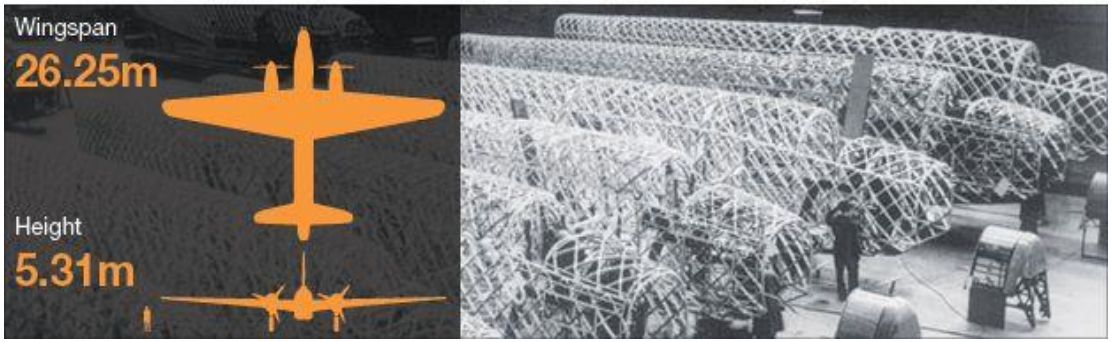


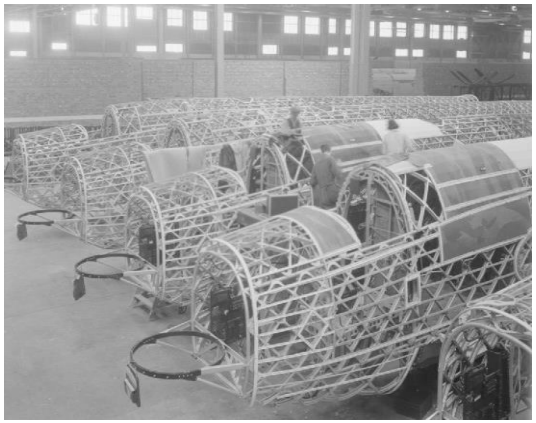
- **Semi-monocoque:** skin is stiffened by longitudinal elements (stiffeners, stringers, longerons)
  - **Stringers (6-10 in. spacing)**
    - increases skin stability
    - carry fuselage bending
    - provide multiple load paths for fail-safe design
  - **Frames** (~ 20 in. spacing)

Fuselage Primary Loads

- Nominal (static)
- Dynamic: Maneuver and Gusts







A restored Wellington bomber, showing its geodetic skeleton, and below, under construction in WWII. This airplane took a lot of heavy flak and damage yet returned the crew safely home, under conditions where other aircraft would have been abandoned. Issue was the low production rate (1 airplane per day), since The structure was built by hand.

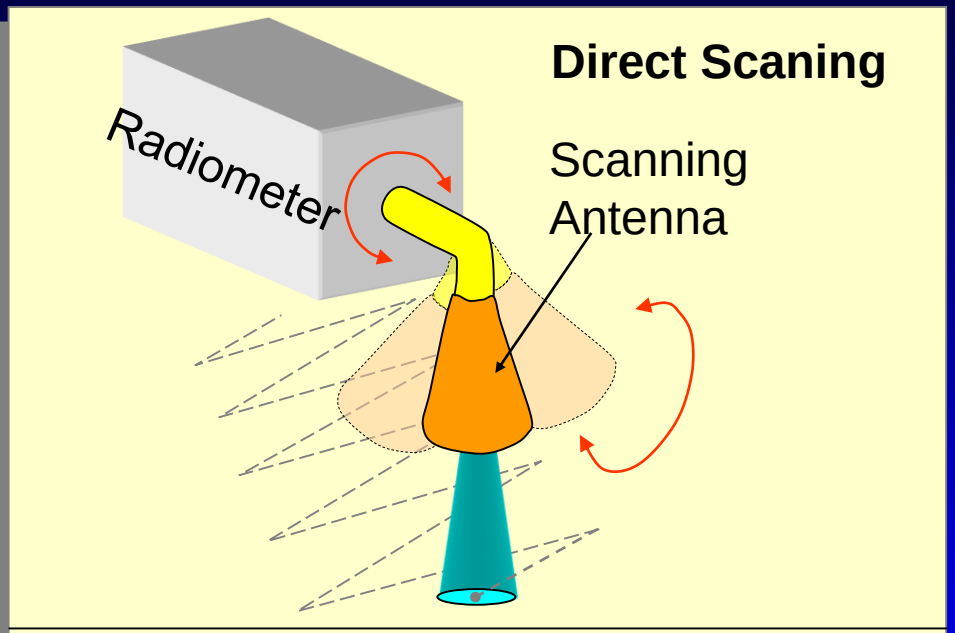
(Wellingtons under construction, showing the geodetic/geodesic airframe)

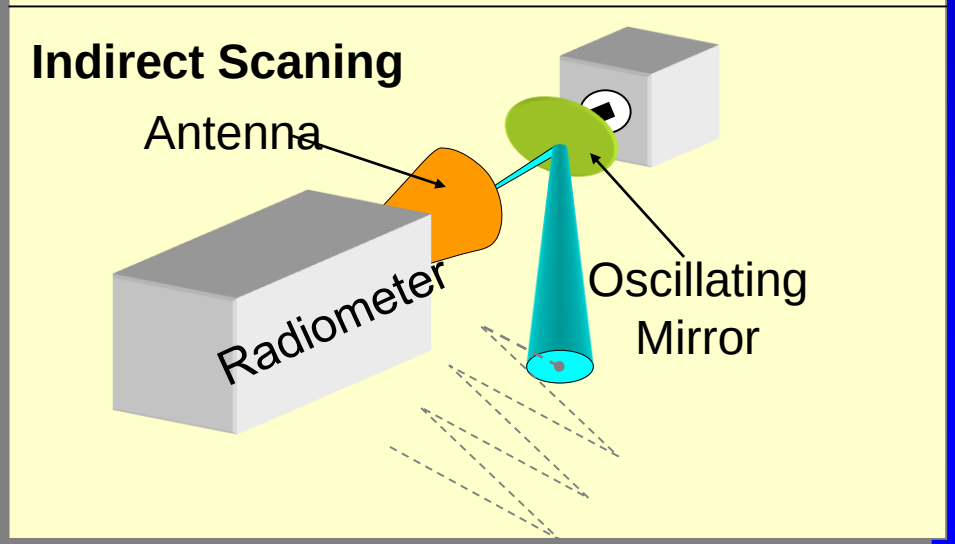
OPPORTUNITIES FOR RESEARCH:

(III)

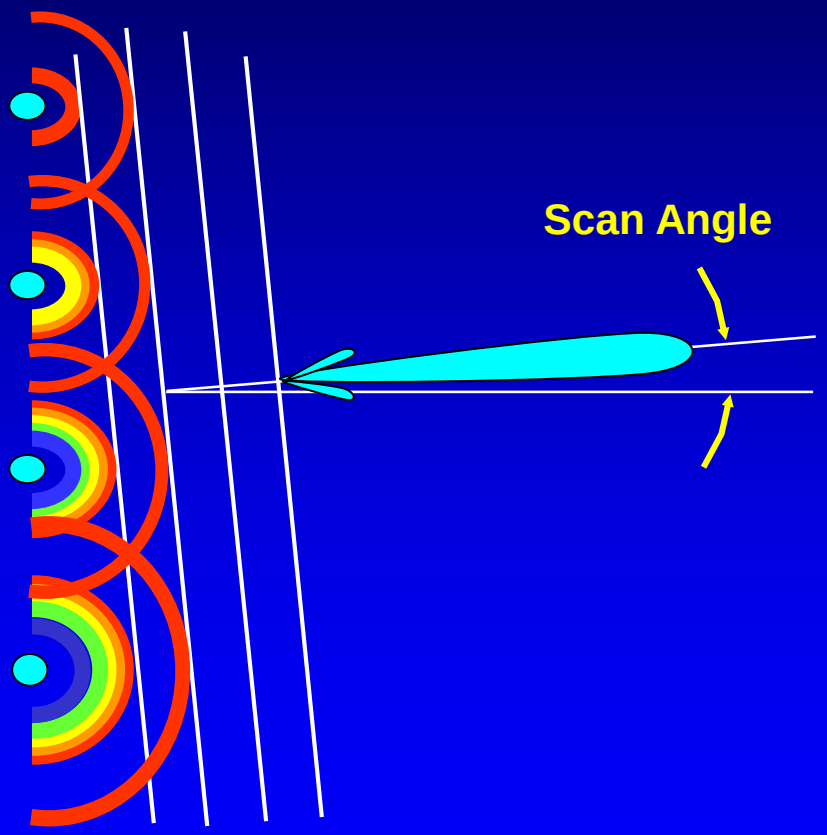
Scanning Radiometers

Mechanical Scanning

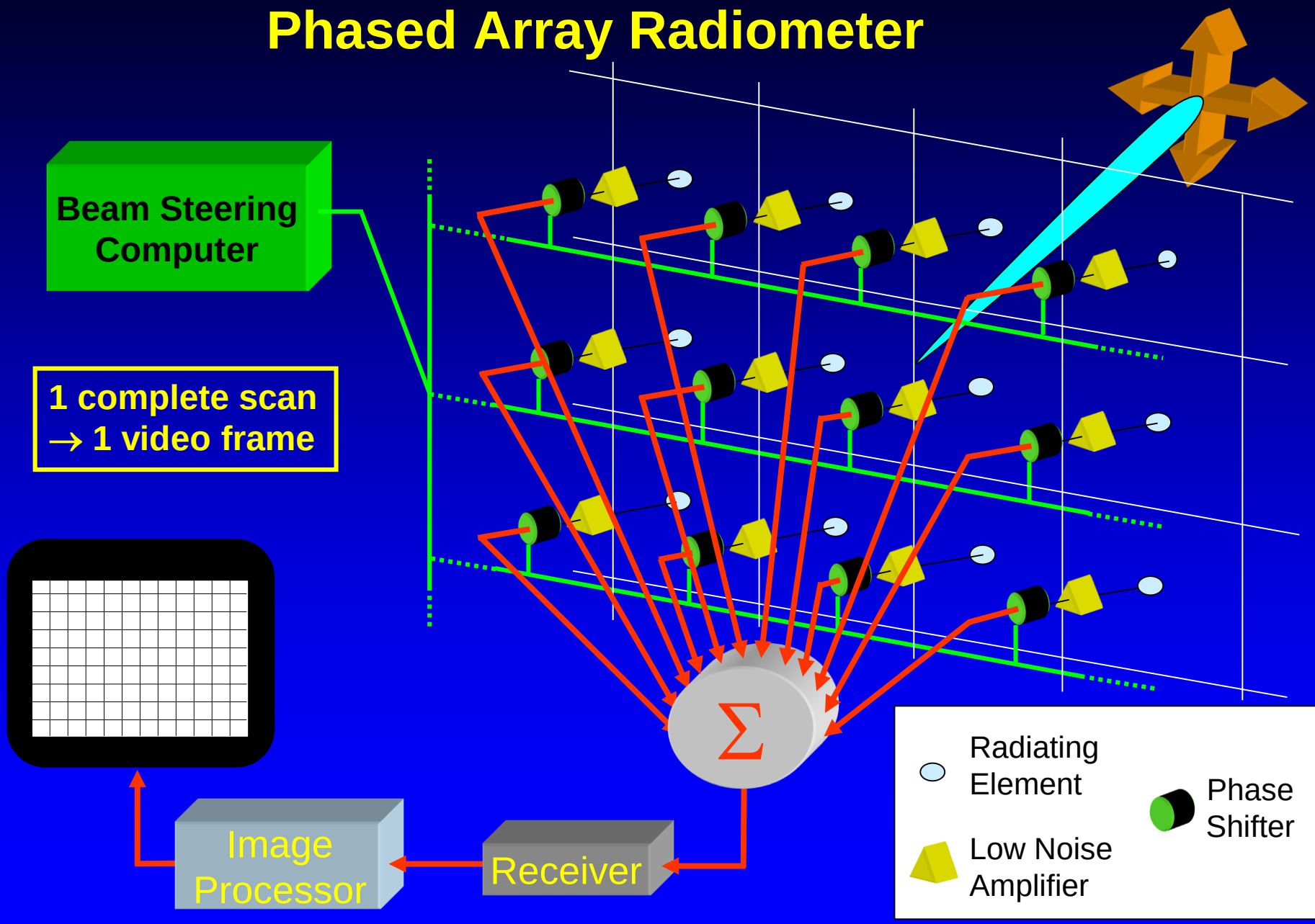


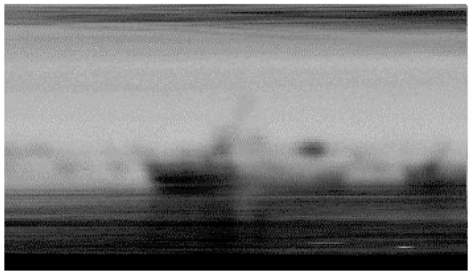


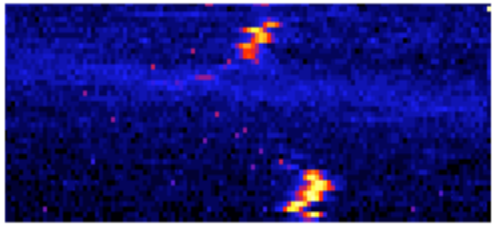
Electronic Scanning



Conceptual Diagram of 2-D Phased Array Radiometer



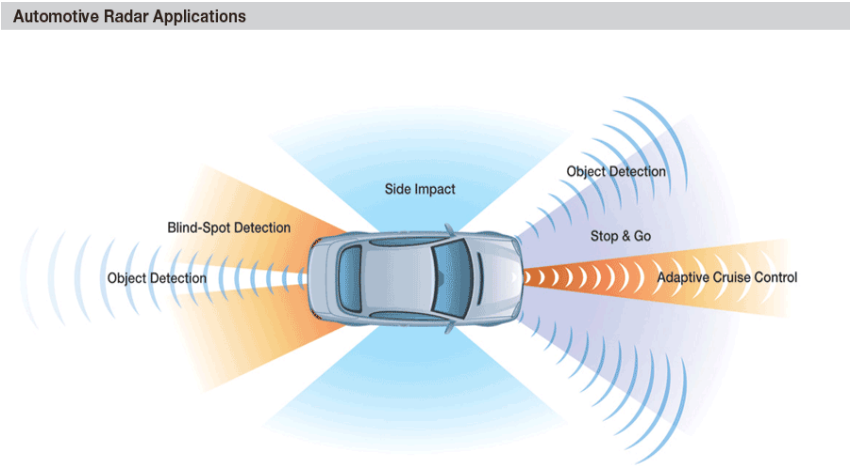


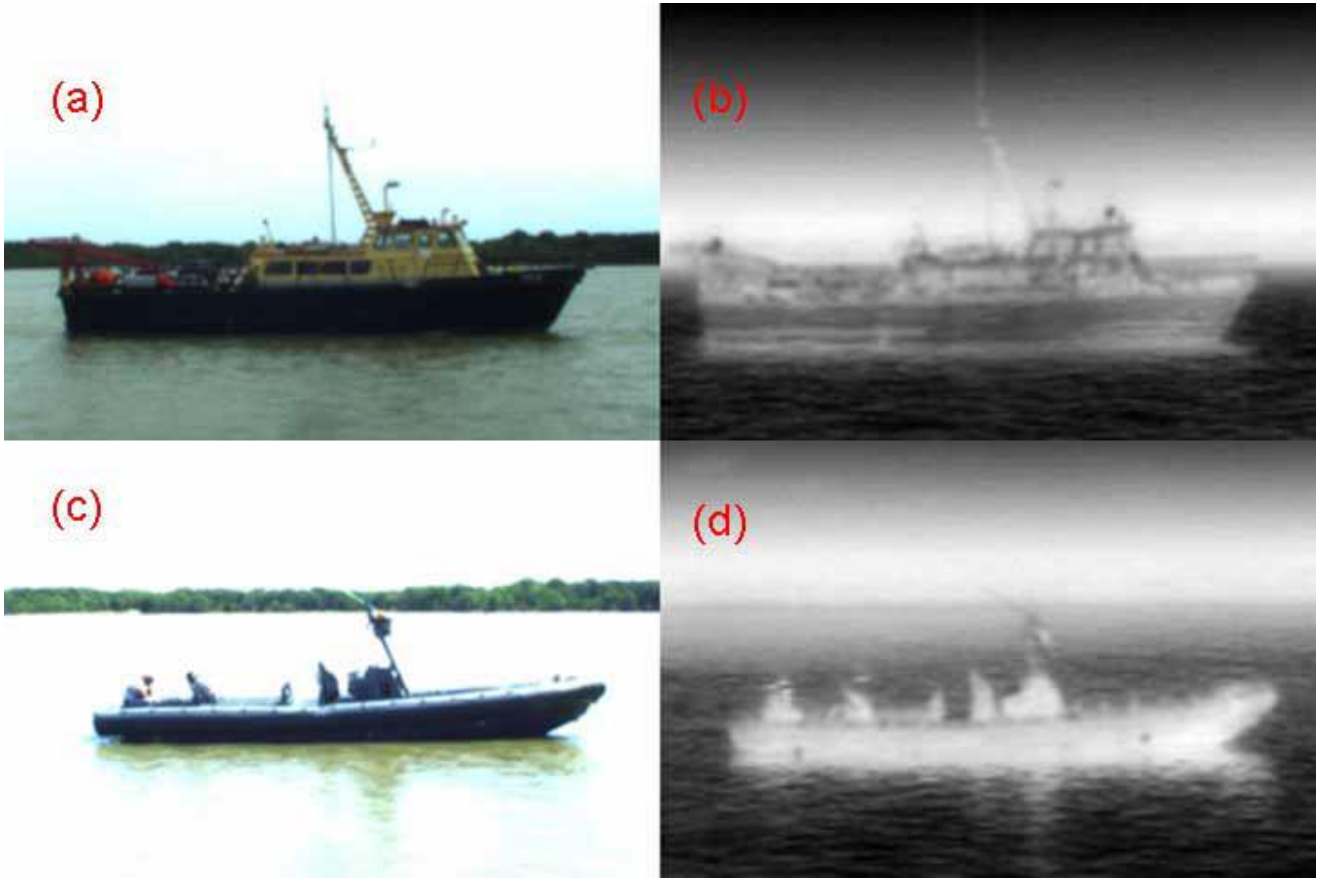


Imaging solutions needed for:

Harbor navigation in dense fog
Military aircraft landing in “brownout” conditions (dust clouds)
Commercial aircraft landing and taking off in harsh weather, particularly dense fog
Emergency personnel tracking during fire and rescue operations
Non-intrusive portal security (airport screenings as well as security in government buildings, sports arenas, etc)
All day, all weather surveillance.

Automobile Radar: 60 – 77 GHZ (short range)





Visible image of the trawler boat (length: **22m), side angle. (b) Passive millimeter-wave image corresponding to (a); detector vertically** polarized. (c) Visible image of men in a rigid-hull inflatable boat (RHIB)- boat length is 3.7m. (d) Passive MMW image corresponding to 6(c). Distance to target is 30m for images (a)-(d).

RESEARCH OPPORTUNITIES (II)

- **IMAGE RECOVERY: Radiative Transfer Formulations, Simulation of Electromagnetic Interactions with media, and Regularization techniques.**

- **Extensive Monte Carlo Simulations of ATMOSPHERIC LAYERS of various densities and hydrometeor/particulate compositions.**

- **RADIOMETER DESIGN: Antenna Simulations, Manufacturing, and Testing. Radiometer field Testing (Engineering). FREQUENCY SCANNING IMAGERS (Electronic beam-steering Phased Array Radiometers).**

- **SUPER-RESOLUTION Algorithms via Tikhonov-Pytiev Regularization. Solve an ill-posed inverse scattering Problem in Millimwter-wave Imaging.**

- **COMPACT AND HEADS-UP DISPLAYS (for pilots). Main customers include Federal Express.**

- **Detection of Ice Crystals, super-cooled water droplets using MMW techniques.**

- **THE 'MUTI-LAYERED' Dielectric Problem.**

STATUS/Summary

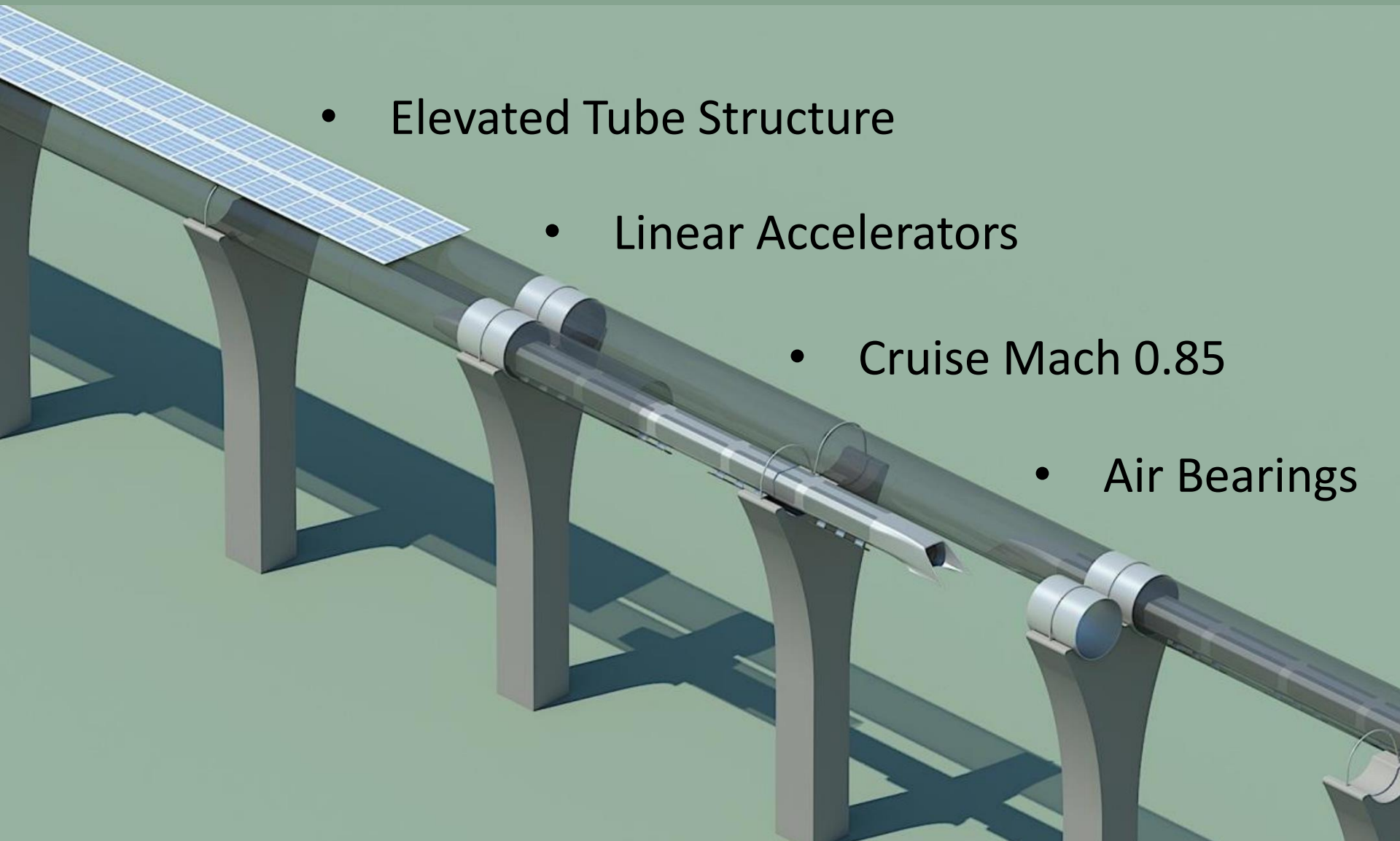
- PMMWI sensors can provide visual-like images through atmospheric conditions that render visual and IR sensors useless. Safety benefits to aviation include EVS(enhanced vision systems), CFIT mitigation, and situational awareness.
- PMMWI has demonstrated applications in homeland security, surveillance, etc.
- Today's low-cost solution is based on optical **beam forming** coupled with **mechanical scanning.** The 94GHz prototype has good performance.
- Scanned systems are much cheaper than focal plane array receivers
- Ideal approach is to have aperture completely filled with receivers and use **electronic beam forming**
- **Future Radiometers** will be compact **phase-array** systems based on advanced chip (MMIC) technologies, and highly sophisticated **super-resolution algorithms**.

OPPORTUNITIES FOR RESEARCH:

(IV)

Hyperloop and Biomimetics: A New Opportunity

Almost a Vacuum Train



- Elevated Tube Structure
- Linear Accelerators
- Cruise Mach 0.85
- Air Bearings

Associating Hyperloop to aeronautics

This is what comes immediately to mind:

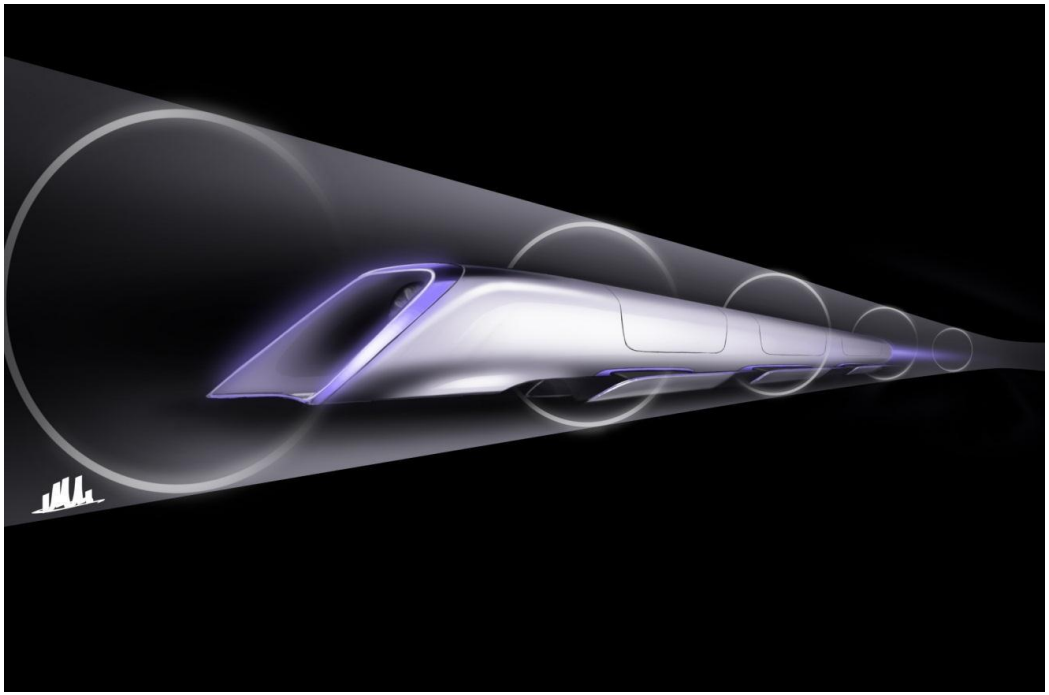
-- **Control and Navigation are critical for Hyperloop Safety** due to high speeds and relatively close proximity to tube. Designs may be translated to aeronautics.

-- **Evacuation procedures** and engineering designs to help ambulation of passengers.

-- **Braking and Acceleration technologies** for Hyperloop may be applicable to Aircraft

-- Aerodynamic heating of tube – **cooling of tube**.

Are there **biomimetic approaches** to solve these problems?



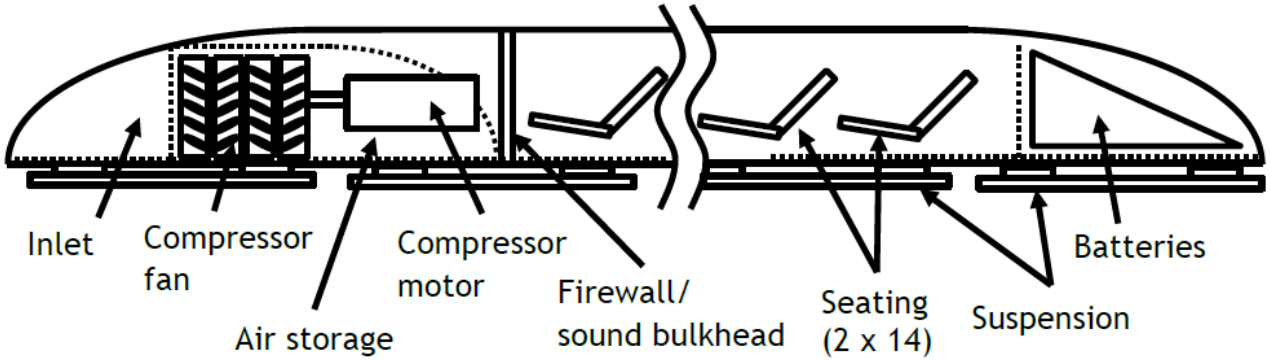
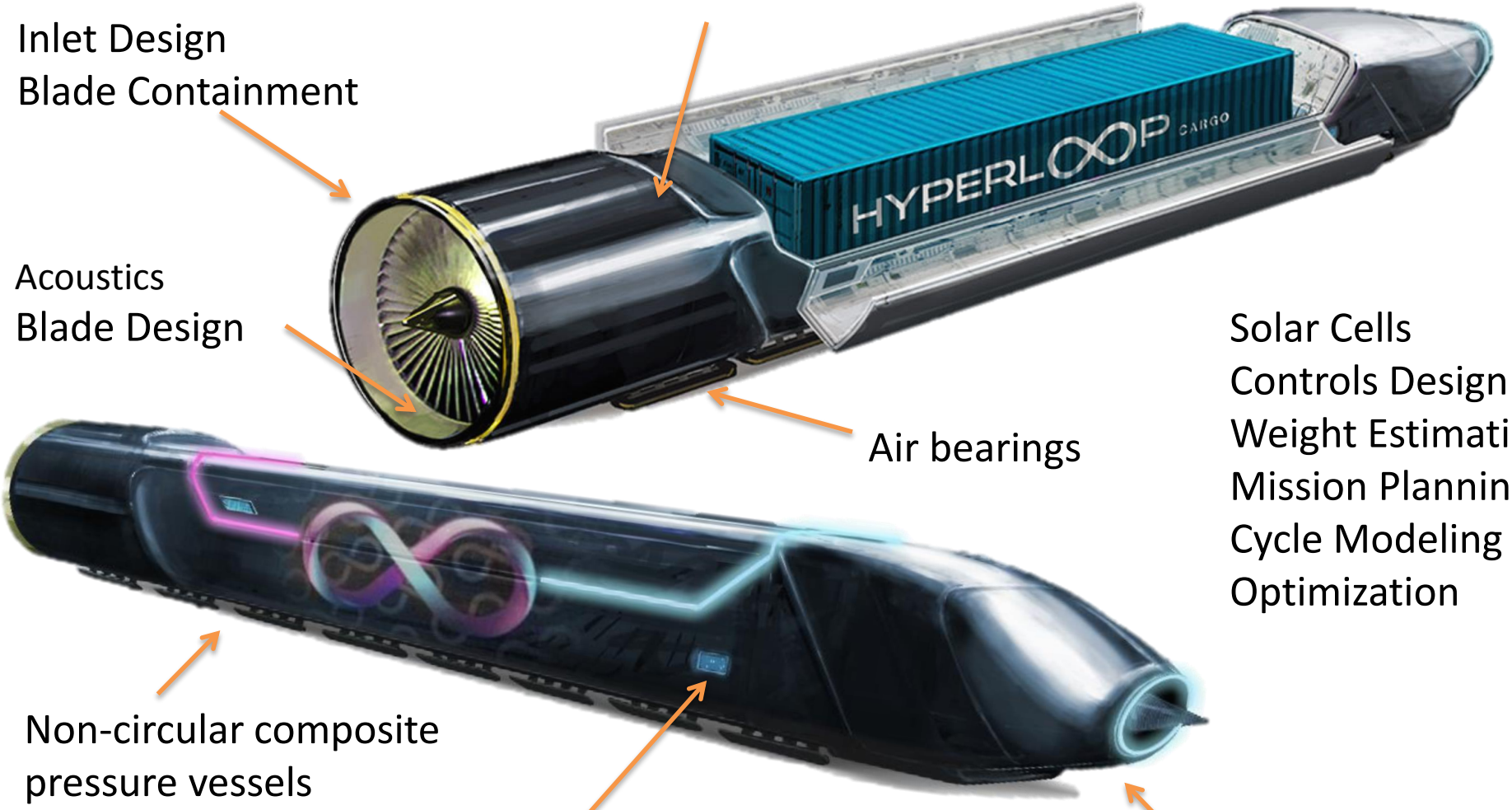


Figure 4. Hyperloop passenger capsule subsystem notional locations (not to scale).

Ground Level Aeronautics: Hyperloop Technology Research



SpaceX Hyperloop Vehicle

Design requires expertise in the areas of:

- Axial compressors
- Composite Materials
- Power and electrical systems
- Mechanical controller design
- Inlets/nozzles
- Air bearings
- Aerodynamic design
- Vacuum systems
- Safety
- Vibrations and Dynamics
- Smart Sensors and Diagnostics
- Avionics and Telemetry

END