

Airship Industry Study: In 2015, NASA Ames Research Center completed a study of the overall airship industry. The project called for a report that describes airship concepts proposed or projects initiated in recent years, airship performance or capability targets, and the missions these activities were addressing. The resulting report details the principal technical features of these airships, the proposed value/advantages of the features, notional concepts of operation, and challenges associated with such vehicles. The study investigated the current status and near-term prospects of these airship development activities, whether they are active or, if curtailed, the circumstances and possible reasons for that conclusion, including technical, business, or other mitigating factors. This presentation provides highlights of the Airship Industry Study investigations, findings, and recommendations.

UAS Carrier Concept: The advantages of utilizing an airship as an airborne carrier for support and deployment of Unmanned Aircraft Systems (UAS) are examined. Whether as a stand-alone platform or in concert with conventional aircraft, the airship UAS carrier provides a number of compelling benefits for both military and civilian missions. As a mobile base it can remain operational despite political fallout that may render ground or ocean based UAS sites unavailable. It offers the psychological impact of a power projection tool that has few geographical limits, and holds promise as a new method for cost-saving intelligence gathering. It is also adaptable for civilian variants for supporting: emergency response, security/surveillance, delivery of medical/food supplies, as well as commercial package delivery to metropolitan and remote communities.



National Aeronautics and
Space Administration



Future Trends in Logistics & Sustainment

9-10 June, 2016

I. Airship Industry Study

II. UAS Carrier Concept

Prepared by: NASA Ames Research Center





Airship Industry Study

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PRESENTATION OUTLINE

- Introduction
- Demand-Side: Airships Missions and Users
- Supply-Side: Airship Companies
- Recent Airship Programs
- Airship Design Trends and Technologies
 - New and Enabling Airship Technologies
- Modeling and Simulation Tools
- Study Conclusions
- Study Recommendations
- Q & A



Ron Hochstetler Lighter-Than-Air Expertise

- Aviation Specialist (SAIC) LTA SME support to SimLabs
- Director, SAIC LTA Programs
- Deputy Program Manager for SAIC SKYBUS 80K UAS airship
- Project Manager US Army “Transport Airship” Study
- Technical support to Phase I DARPA “ISIS” stratospheric airship
- Senior Project Analyst for CargoLifter GmbH, Germany
- Program Manager supporting US Navy Airship Program Office
- Tour Manager for Airship Industries commercial airship
- Assistant to Program Manager for YEZ-2A Navy airship
- Mechanic/Assembler on Helistat heavy lift hybrid airship



Piasecki Helistat hybrid rotary airship



US Navy YEZ-2A airship mockup



1988 Pepsi airship tour



CargoLifter heavy lift airship concept



DARPA ISIS stratospheric concept



SAIC SKYBUS 80K



INTRODUCTION

- **There is an ongoing Government interest in the potential of airships for cargo transport**
 - Conducting vertical or near-vertical airlift of heavy, outsized freight with little or no ground infrastructure is an attractive cargo transport option
- **USTRANSCOM wanted to understand the principal issues that are holding back commercial development of airship transports**
- **NASA Ames Research Center was commissioned by USTRANSCOM to study the airship industry's ability to design, develop, and operate cargo airships**
- **Principal study objectives were to identify:**
 - Current and near term state of the cargo airship industry
 - Roadblocks hindering cargo airship development
 - Steps needed to remove impediments to cargo airship deployment



Demand Side: Airships Missions and Users

- Interest in cargo airships greatest since the age of the great rigid airships
 - Commercial airship transport ranges from tens of miles to a few hundred miles (highest demand), with a small number of long distance missions
 - Threshold demand for airship transport of 10 to 15 tons, with a middle range demand around 45 to 50 tons, rising to interest in 150 tons plus
- Principal commercial application supporting "resource extraction"
 - Airship provides access to remote or difficult to access areas where conventional transport is prohibitively expensive or environmentally restricted
- Particular interest in moving outsized or heavy "project freight"



Canadian northern home construction



Heavy vertical lift



Equipment transport

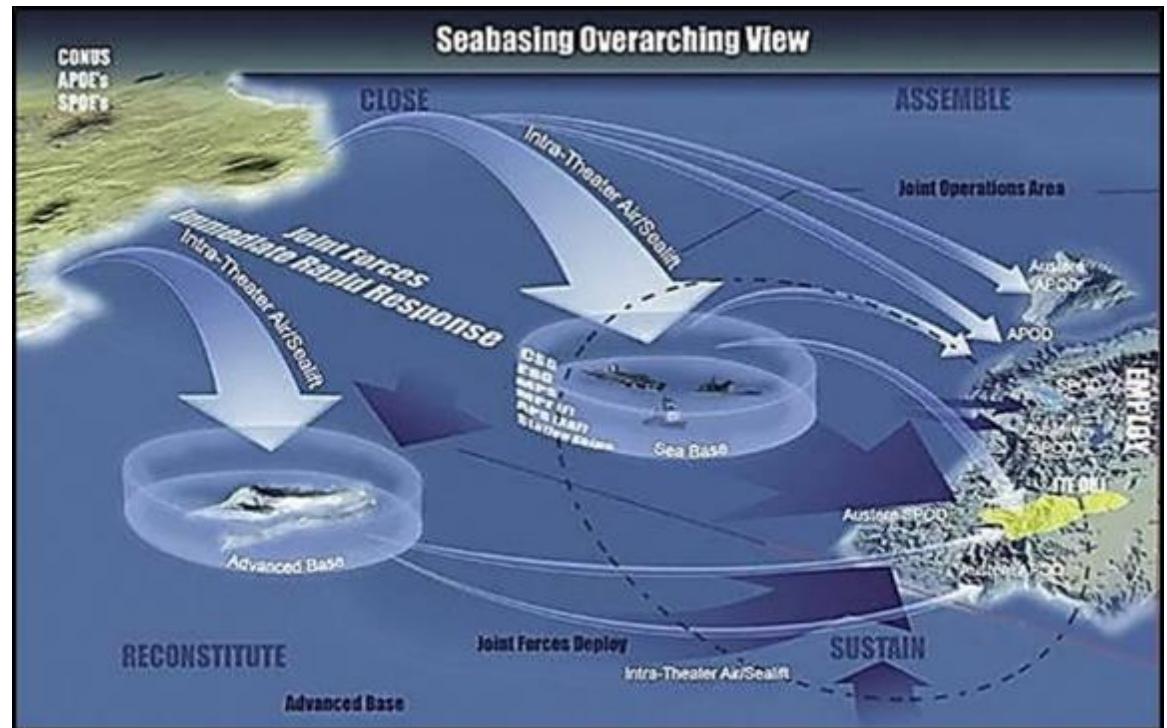


Canadian ice road replacement



Demand Side: Airships Missions and Users (cont.)

- DoD demand is for insertion of materials into critical points not easily reached
 - Reduce number of moves required in the Area of Operations
 - Provide US forces with advantage of adaptive power projection
 - Move new things in new ways (support to Seabasing concepts, etc...)





Supply Side: Airship Companies

- Industry survey assessed capabilities of 51 organizations
- **Seven companies represent majority of existing airship operators**
 - Five (all manufactures) have aerostat operational capabilities
 - Thirty six companies have potential (or aspiration) to develop and manufacture their LTA designs
 - Three firms were focused on LTA design only with no manufacturing interest
- **Eighteen firms active designing, building, or operating airships or aerostats**
 - These were funded with full-time staff and currently offering airships, aerostats, or operating LTA systems (or able to do so)
- **Thirteen firms had some level of funding, some staff (mostly part-time)**
 - But did not yet have an ongoing business of supplying or operating LTA vehicles
- **Fourteen firms had some level of LTA design or development commitment**
 - But not actively moving forward due to insufficient or pending funds



Recent Airship Programs

- Hybrid Air Vehicles (HAV) converted LEMV into proof-of-concept commercial cargo airship demonstrator (soon to make first flight)
- Lockheed Martin ready to construct several LMH-1 commercial cargo hybrid airships pending market orders



LEMV hybrid airship



Lockheed Martin LMH-1 hybrid airship concept

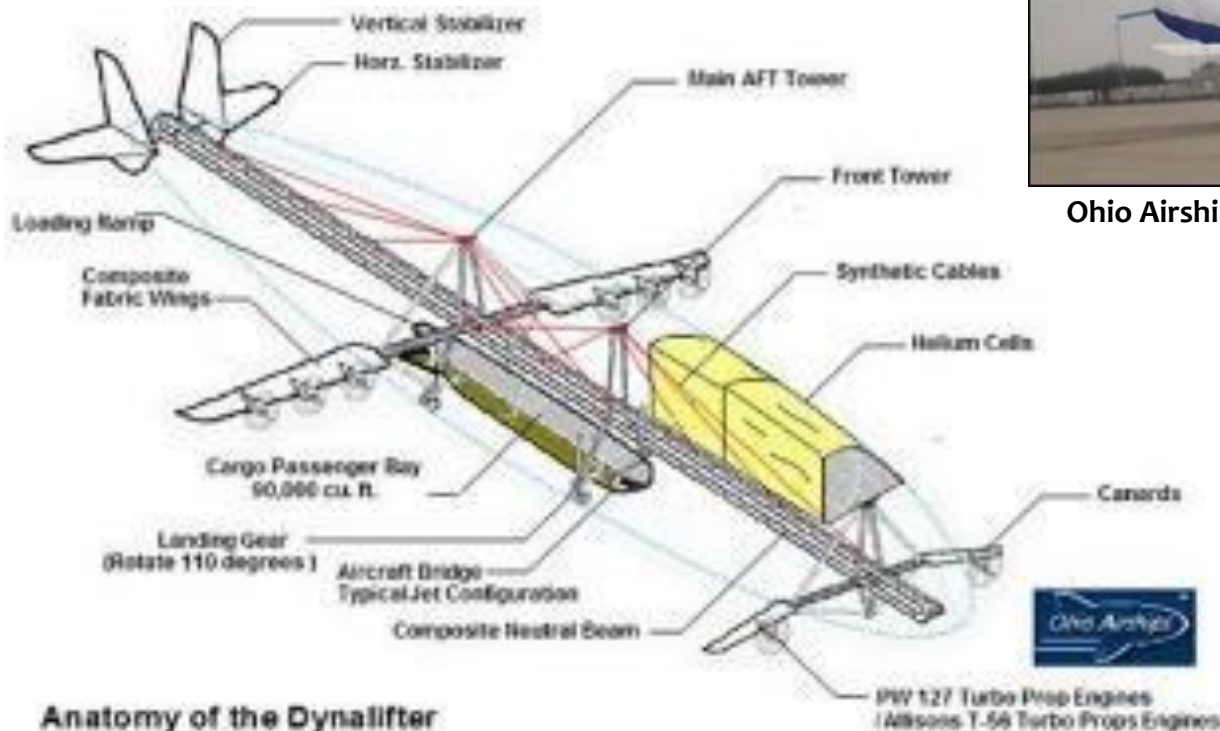


Recent Airship Programs (cont.)

- Ohio Airships taxi tested proof-of-concept “winged” hybrid cargo airship



Ohio Airships demonstrator rotational flight test





Recent Airship Programs (cont.)

- Millennium Airships plan to develop SkyFreighter rigid shell cargo airship employing a thrust augmented vectoring propulsion/airfoil
- TP Aerospace is finalizing design of ATLAS 50 cargo airship
 - Uses electric propulsion and both roll-on-roll-off and hovering payload deliveries



Millennium Airships Skyfreighter with its four ThrustWings



TP Aerospace
ATLAS 50
unloading at
austere site



TP Aerospace inflatable rigid hull structural layout

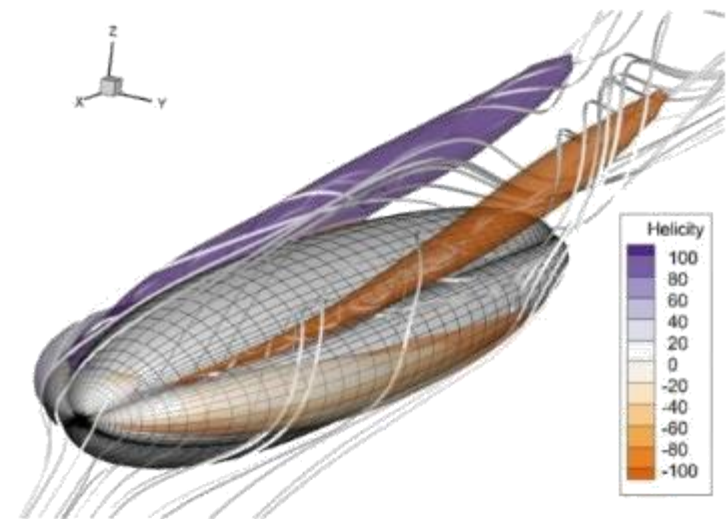


Recent Airship Programs (cont.)

- The French Dirisolar company is designing their fully solar powered electric DS 1500 proof-of-concept airship using aluminum tubing and sail fabric
- Another French company, A-NSE is investigating their unique variable shape and variable volume non-rigid airship concept
 - May enable optimization of airship hulls for high speed, or for hovering flight by changing hull shape as needed



Dirisolar concept installation of solar cells



CFD simulation of A-NSE side lobe design concept



Recent Airship Programs (cont.)

- An Argentinian firm Aerovehicles is progressing through initial design of their Aerocat rigid hybrid cargo airship concepts
- Zeppelin NT maintains their airship design, manufacturing, and operational experience providing 3 new Zeppelin N 07 airships to Goodyear



Aerovehicles Aerocat R-40



Goodyear Zeppelin N 07 in flight

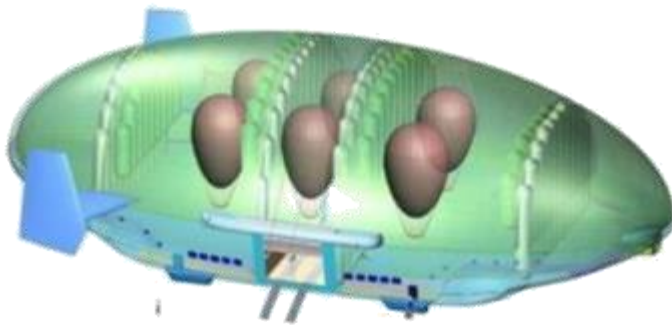


Zeppelin N 07 assembly at Goodyear hangar



Recent Airship Programs (cont.)

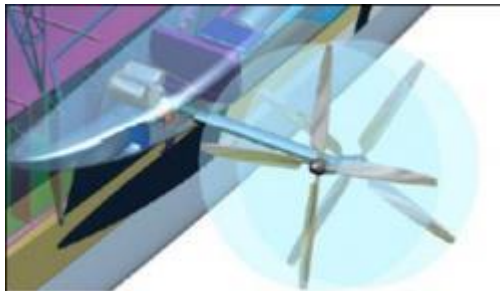
- Two Russian companies RosAeroSystems and Airship GP proposing heavy lift commercial cargo airship designs, with each incorporating several novel technologies not employed in previous airship designs



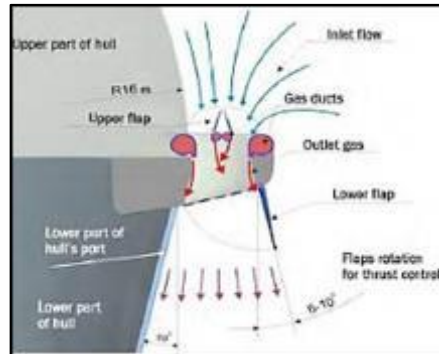
RosAeroSystems ATLANT with internal hydrogen ballonets



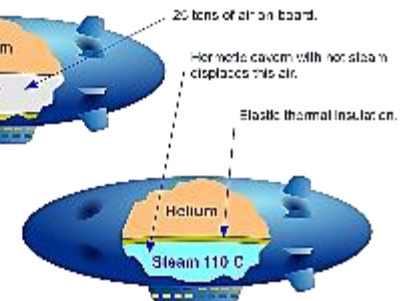
Airship GP Super-hybrid



ATLANT turboprop and turbojet lifting engines



Layout of Super-hybrid internal propulsion units

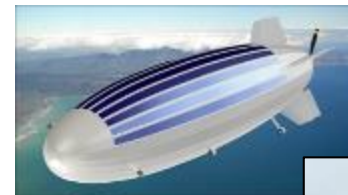


Super-hybrid helium and air/steam chambers



Airship Design Trends and Technologies

- Near-buoyant airship with single ellipsoidal shape and hybrid designs combining gas lift with the dynamic lift of an airplane or helicopter
- Other airship shapes are being explored:
 - Winged and rotary hybrid
 - Lenticular, deltoid, and spherical hulls
- Airship hulls compromise between exclusive performance capabilities
 - Streamlined hull for high speed long distance operations
 - Non-directional hull for hovering precision and wind gust mitigation
 - With hovering cargo delivery airship doesn't land to pick up or deliver cargo



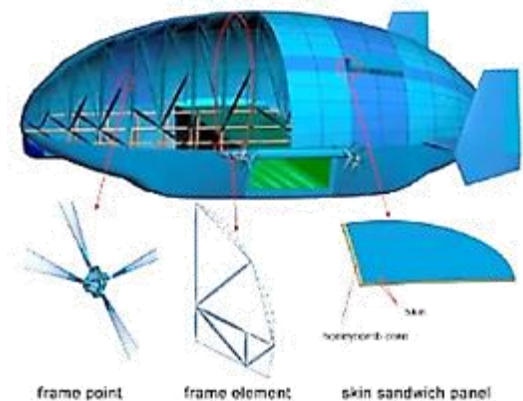


Airship Design Trends and Technologies (cont.)

- **Airships combine modern rigid and fabric structures**
 - Strength-to-weight ratios of airship fabrics increasing. Most popular include Vectran and Technora
- **Chromoly-4130 tubing and aluminum still in use but Kevlar, graphite laminates, and Nomex honeycomb being adopted**
 - Aerospace composite tubing used for gondolas, (majority of Zeppelin N 07 hull is made of graphite tubes)
 - TP Aerospace “rigid” hull structures made of inflatable high pressure fabric tubes
- **Some rigid hulls combine internal rigid parts (longerons and stringers) with lightweight rigid shell**
 - One rigid shell airship uses aerospace aluminum sheet while others use rigidized sheets of composite fabric



TP Aerospace “Airbeam”
suspending a car



ATLANT structure and skin



Airship Design Trends and Technologies (cont.)

- **Aerospace and non-aerospace engines used, none are optimized for airships**
 - Aero-diesels are in use (350 hp) but larger airships need high power versions
 - Turboprops are being chosen despite higher fuel consumption
- **New propulsion alternatives include:**
 - Electric motors powered by solar cells, and hybrid-electric systems combining diesel engine and electric generator
 - An airship was test flown using diesel engine driving a hydraulic pump to power hydraulic propulsion units mounted on the airship hull



LEMV 350 hp aero-diesel



Blue Devil 2 TPE331-12 turboprop

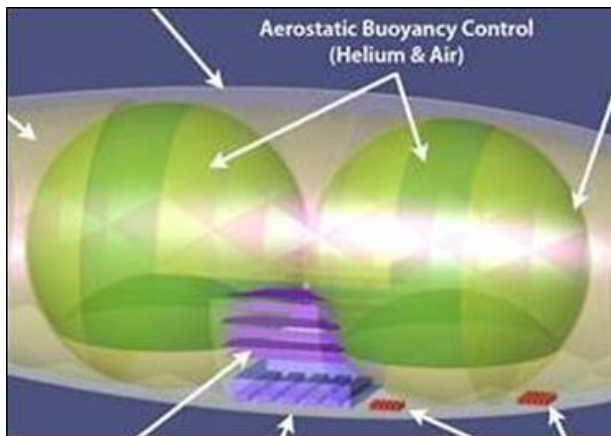


Polar 400 hydraulic powered airship



Airship Design Trends and Technologies (cont.)

- **Designers developing methods to control airship buoyancy**
 - Compress the lifting gas and store it onboard
 - Heat the lifting gas to increase its volume and subsequent lift
 - Use superheated steam as a cheap, safe lifting gas that can be vented
- **Russian patent issued for a chemical additive rendering hydrogen non-flammable (Russia Patent No. 2441685, 2 October 2012)**
 - Allows safe use of cheap hydrogen as lifting gas that can be vented



Skylite GeoShip buoyancy compensation system

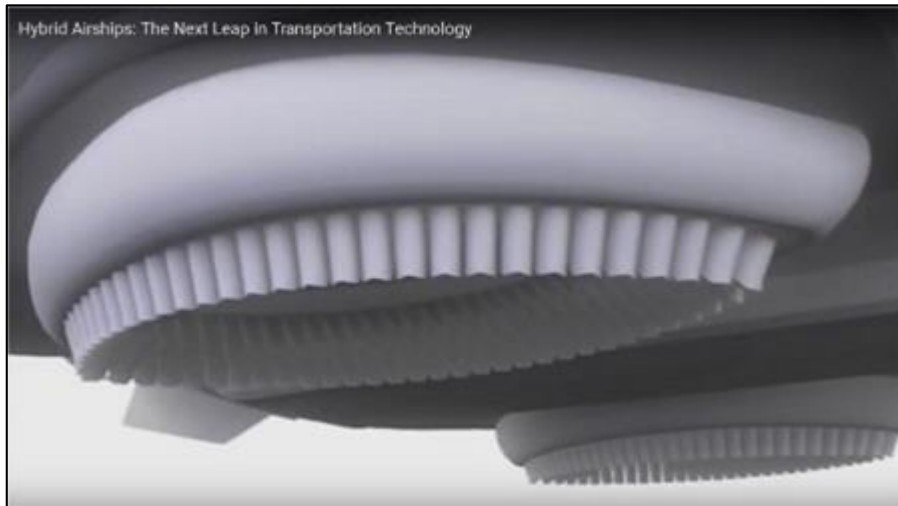


Steam balloon

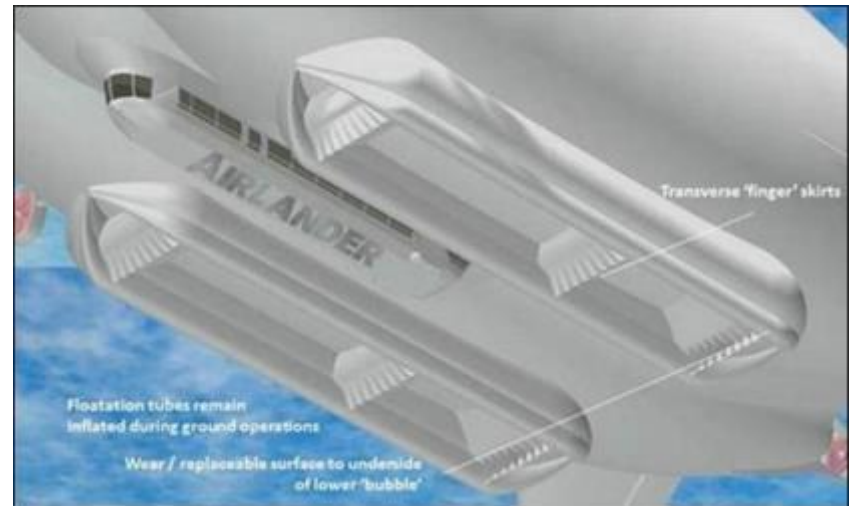


Airship Design Trends and Technologies (cont.)

- Designers of hybrid lifting body airships are incorporating air cushion landing systems (ACLS)
- These hovercraft systems allow the airship to land and taxi on undeveloped surfaces, and bodies of water
 - ACLS promises independence from prepared operating ground sites



Lockheed Martin LMH-1 ACLS skirts



HAV AIRLANDER ACLS skirts deployed for landing



Airship Design Trends and Technologies (cont.)

- **Airship cargo handling systems**

- Internal carriage with conventional roll-on-roll-off ramps into a payload bay
- Carriage of large, outsized loads or standard shipping containers externally attached below the airship
- Sling load systems being designed for hovering payload delivery



Lockheed Martin LMH-1 unloading CONEX box



USIC concept for external attachment of cargo boxes

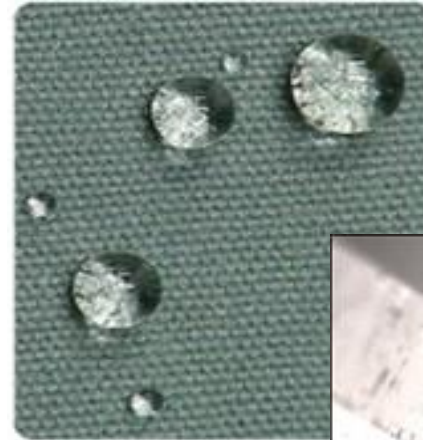


Lockheed Martin hybrid with sling load

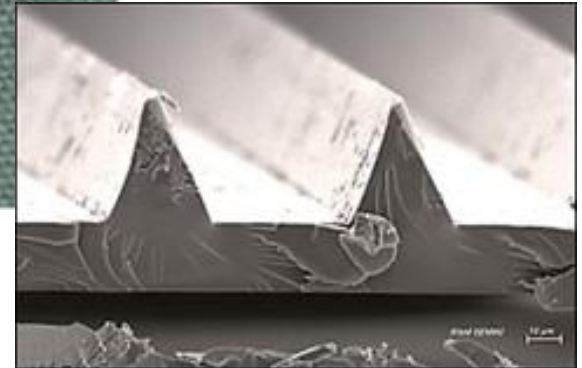


New and Enabling Airship Technologies

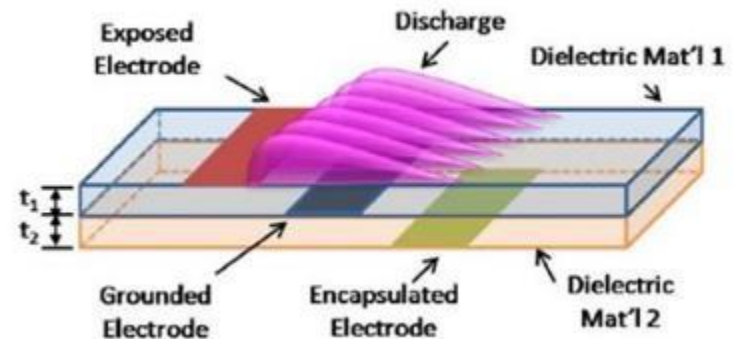
- New technologies offer substantial advantages for cargo airship operations
 - Specially molded micro "riblet" structures, similar to shark skin, applied to LTA hull surfaces may reduce drag by 6.25 %
 - Hydrophobic surface treatments that strongly repel water may reduce accumulation of rain, snow, and ice
 - Solid-state circuits convert electricity into plasma flow accelerating air adjacent to hull skin could provide low power propulsion (25 kt. +) and boundary control to reduce hull drag



Hydrophobic coating



Electron micrograph of "shark skin" coating

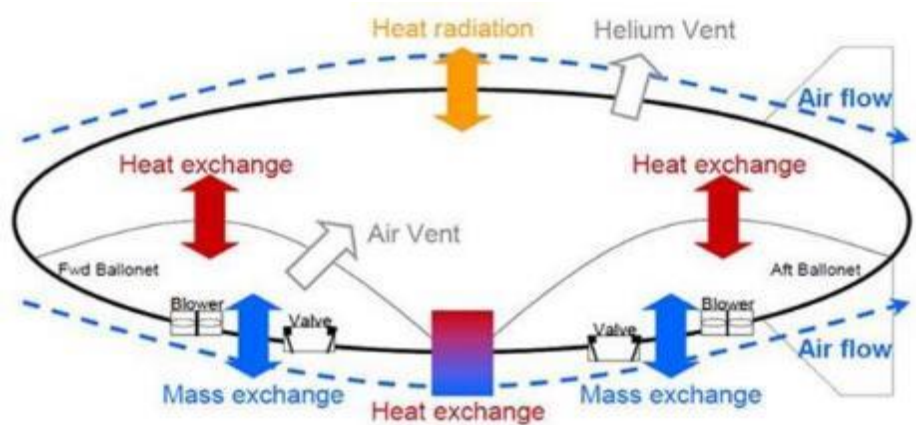


A multi-barrier plasma actuator schematic

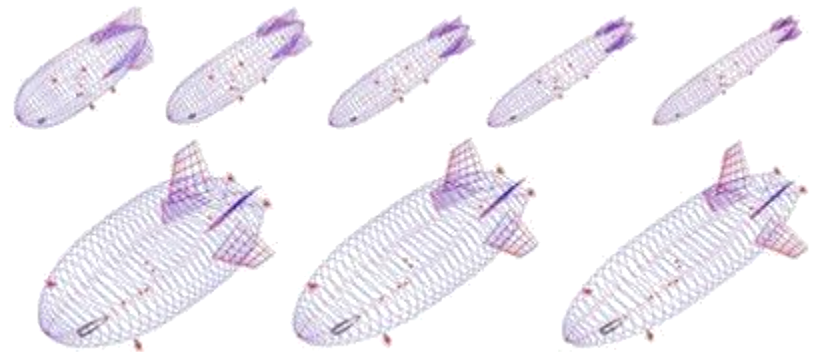


Survey of Airship Modeling and Simulation Tools

- Survey looked at nine modeling and simulation tools developed for airship sizing, design, development, and operations
- Other tools in existence were considered proprietary by owners, and were not made available for this study
- Gap analysis identified tool development required to meet needs of current and future airship design efforts



CargoLifter Thermodynamic/Aerostatic model



Advanced Airship Analysis and Design (A3D) tool



Modeling and Software Tools Gap Analysis Part 1

Airship Modeling and Simulation Tool Attributes

NAPSAP	YEZ-2A	OAR	ASPEN	Cargo Lifter	Burgess-Mayer	LTASIM	AOM	A3D (AFRL)
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Concept Studies and Design Trades

Airship sizing and weight
Performance/Mission parameters
Mission requirements development
Project schedule
Business plan and costs
Concept of operations (CONOPS) development

Functional	None	None	Marginal	Functional	Functional	Functional	Marginal	Functional
Functional	Marginal	None	Functional	Functional	Functional	Functional	Functional	Functional
Functional	Functional	None	Marginal	Functional	Functional	Functional	Functional	Functional
None	None	None	None	Marginal	Functional	None	None	Functional
None	None	None	None	Marginal	Functional	None	Functional	Functional
Functional	Functional	Functional	Marginal	Functional	Functional	Functional	Functional	Functional

Modeling, Analysis, and Simulations

Numerical modeling (CFD, FEM)
Aerodynamics
Aerostatics, aeroelastics, and thermodynamics
Flight mechanics and dynamics
Loads computation and interface loads
Concept of operations (CONOPS) simulation

None	Functional	None	None	Functional	None	Functional	None	None
None	Marginal	None	None	Marginal	Marginal	Functional	None	Functional
None	None	None	None	Marginal	None	None	None	None
None	Functional	None	None	Marginal	Functional	Functional	None	Marginal
None	Marginal	None	None	Functional	None	Marginal	None	None
Marginal	Functional	Functional	Marginal	Functional	Marginal	Functional	Functional	Functional

Tool Capability:

Functional
Marginal
None



Modeling and Software Tools Gap Analysis Part 2

Airship Modeling and Simulation Tool Attributes

NAPSAP	YEZ-2A	OAR	ASPEN	Cargo Lifter	Burgess-Mayer	LTASIM	AOM	A3D (AFRL)
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Design and Specification Development

Overall airship layout
Structures (rigid and fabric)
Propulsion (engines and props)
Cargo carriage and handling
Weights
Flight control system
Ground handling systems

Functional	Marginal	None	None	Functional	Marginal	Marginal	Marginal	Marginal
None	None	None	None	Functional	None	None	None	None
None	None	None	None	Functional	None	None	None	None
None	None	None	None	Marginal	None	None	None	None
None	None	None	None	Functional	Marginal	None	None	None
None	None	None	None	Marginal	None	None	None	None
None	None	None	None	None	None	None	None	None

Analysis in Certification Phases

Transient, flight, and mission phases
Stability and controllability
Mission performance capability
Manufacturing and assembly process

None	Marginal	Functional	None	Marginal	None	Marginal	None	None
None	Marginal	None	None	Marginal	None	Marginal	None	None
None	Marginal	Functional	Marginal	Marginal	None	Marginal	None	None
None	None	None	None	None	None	None	None	None

Tool Capability:

Functional

Marginal

None



Modeling & Simulation Tools Survey Findings

- **Some tools have limited capability, but none are fully developed, validated models**
 - Several tools are outdated, have low fidelity, or lack depth of analytical insight
 - Most provide sizing and assessments of design, mission, CONOPS, and mfg costs
 - Only three tool sets had capabilities beyond airship sizing (CargoLifter had detailed analysis)
- **Costs and competitive secrecy are factors limiting creation of airship simulation tools**
 - No incentive for airship firms to create modeling and simulation tools useful to competitors
 - Modeling tools take a back seat to cost of constructing the actual vehicle
 - Extrapolations from inaccurate models propagates financial uncertainty and technical risk

None of the tools surveyed represented single-discipline programs developed for high-fidelity analysis of detailed designs for modern airships



Airship Industry Study Conclusions

- Significant airship industry capability exists to develop cargo airships
- The airship industry is aging and fragmented among a few, small-sized companies and independent airship engineers
- The aerospace community offers a rich source of technologies and development tools useful to the airship industry
 - New materials, propulsion systems, and control software are available to enable the construction and operation of large modern airships
- An industry accepted airship engineering database has yet to be defined
 - This knowledge is not collected or archived in a single authoritative location
- Group of potential airship users is expanding but commitment of funds for airship utilization constrained due to lack of assurance (confidence) in the viability of airship technologies and airship operational cost/effectiveness
- Conundrum is that little investment in airship development is made available until a flight test prototype can be demonstrated to work
- Consequently, the money to design, build, and fly a prototype is dependent on assurances the vehicle will perform as intended



Airship Industry Study Conclusions (cont.)

- What's missing is an airship expert resource that can provide the comprehensive, validated analytical tools needed to aid airship developers in their decision-making about proposed airship designs, technologies, and operations
- This is a persistent obstacle that has kept the airship industry from breaking through into sustainable production of capable airships for market segments that clearly wish to utilize them
- Today's potential airship users and investors also require technical and operational insights that can provide them with a solid basis for making confident investment decisions about particular airship concepts or operational proposals
- However, there is no independent entity that can provide analytical insights in sufficient detail to offer a credible response to questions from potential airship users or airship industry investors as to the technical viability of an airship design or its likelihood of operational success.



Recommendations

A complete and integrated set of airship modeling and simulation tools is needed, based on a full understanding of fundamental airship properties

Assemble an LTA Knowledge Base and Tool Set

- 1. Collect LTA design and operations data in one searchable on-line repository**
- 2. Develop a design process tool set specifically for airship vehicles**
- 3. Establish validated set of modeling and simulation tools for use by airship firms**
- 4. Develop cost analysis tools for airship design, manufacture, and operations**



Recommendations (cont.)

Utilize the Tools and Knowledge Database

1. Investigate critical LTA design concepts, structures, materials, or sub-systems
2. Conduct operational analysis of LTA vehicles and CONOPS to identify challenges
3. Conduct modeling and simulation studies of LTA mfg concepts and techniques
 - a) Reduce labor and assembly costs, improve airship maintenance in the field



Recommendations (cont.)

Private-Public Airship program

- Government (USTRANSCOM) could provide leadership for a public-private-partnership for research into cargo and UAS carrier missions
- NASA Ames can provide guidance for developing engineering tools for the airship transport industry
- Private-Public Airship program utilize commercial airship for development and validation of airship modeling and simulation tools





Presentation SUMMARY

- **Conducted NASA Industry Study for USTRANSCOM**
- **Surveyed publicly available information for Airship Modeling and Simulation Tools**
- **Survey and GAP Analysis of Tools indicates:**
 - Tools are needed in the public domain for high-fidelity analysis and design for modern airships
- **Recommendations :**
 - Assemble and Utilize an LTA Knowledge Base and Tool Set that will be available in the public domain
 - Establish a Private-Public Airship program to develop and validate tools to benefit the Airship Community



Questions?

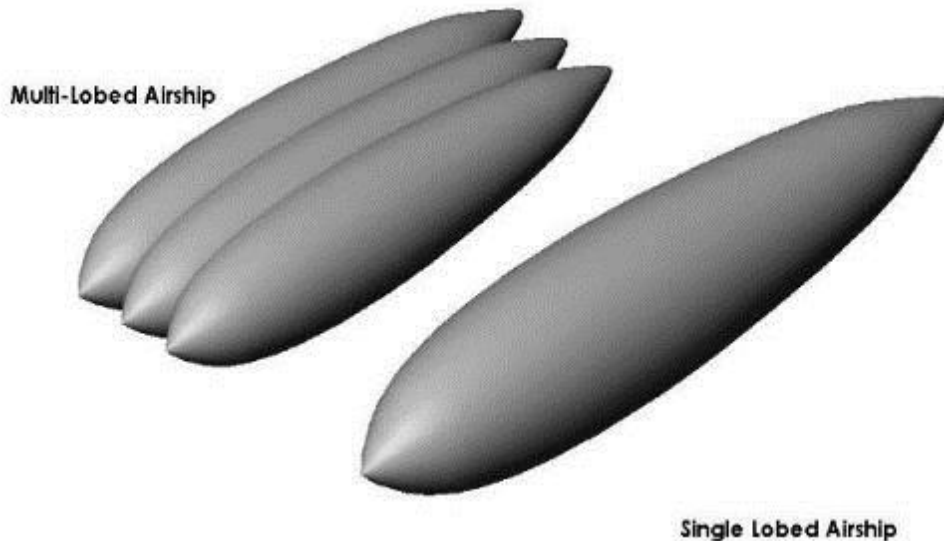


Backup Slides



Conventional Airships vs Hybrid Lifting Bodies

- Conventional hull is inherently more stable in pitch due to lower center of gravity
- Conventional hull has less surface area than multi-lobed hybrid of same gas volume
 - Hybrid requires more fabric
 - Hybrid empty weight is heavier
 - Hybrid has greater drag, producing greater fuel consumption

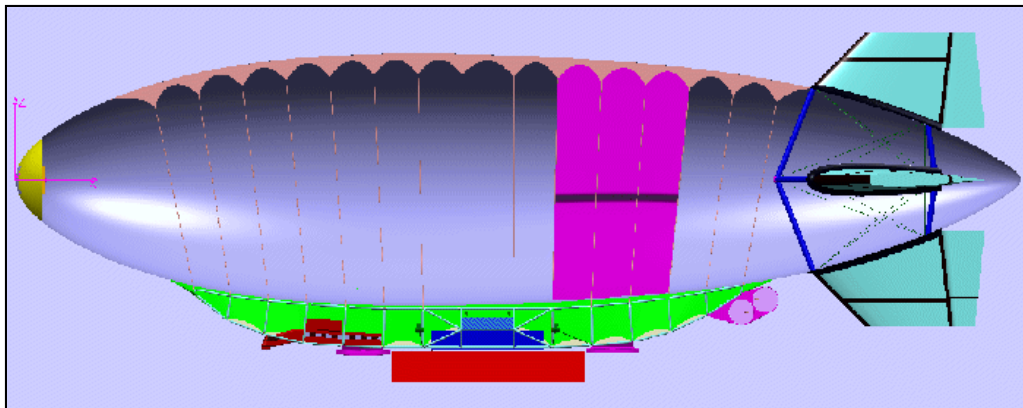


A lifting-body hybrid with three lobes separated horizontally by half of the lobe diameter will have a 6% greater surface area than a single-lobed airship of the same gas volume. The three-lobed hybrid also will have a frontal area that is 23% greater than the single-lobed airship.

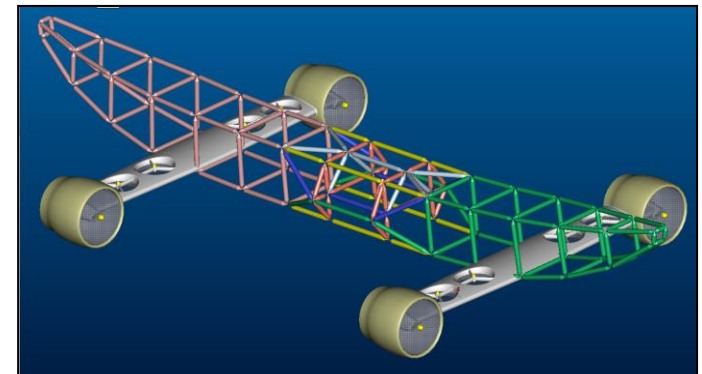


CargoLifter – Late 1990's

- Design and manufacture CL-160 - 160 metric ton lift cargo airship
- Computer controlled propulsion and positioning systems
- Vertical thrusters provide 40 tons of lift
 - Bow/stern thrusters provide positioning stability during load exchanges and mooring
- Semi-rigid graphite composite tubular keel
- 16 GE turboshaft engines for primary propulsion, station keeping, and ship's power
- Featured a crane for vertical payload exchange with ground based ballast
- Did not need to land to load or unload payload



Side view of CL-160 structural concept



CAD rendering of CL-160 gondola structure



National Aeronautics and
Space Administration



Lighter-Than-Air (LTA) “AirStation” Unmanned Aircraft System (UAS) Carrier Concept

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National Aeronautics and
Space Administration



Outline

- Introduction
- Background
- UAS Carrier Airship Concept of Operations (CONOPS)
 - Launch and Recovery
 - UAS Operations
 - Refueling
 - UAS Aircraft and Payloads
 - Airship Survivability
- Hypothetical UAS Carrier Mission
- UAS Carrier Airship Development Program
- Conclusions
- Q & A



National Aeronautics and
Space Administration



Introduction

- **Current Airship Operations**

- Provide surveillance over large geographic areas
- All sensors concentrated within the airship itself
- Airship must be in areas directly observed



**Long Endurance Multi-Intelligence
Vehicle (LEMV)**

- **Future UAS Operations**

- DoD to deploy UAS from jets and turboprops (Gremlins & Arsenal Plane)
- Utilizing a carrier increases overall UAS endurance
- Allows for a distributed sensor net
- A flying carrier provides a mobile UAS base of operations with few geographical limits



Depiction of DARPA Gremlins



Depiction of proposed Arsenal Plane



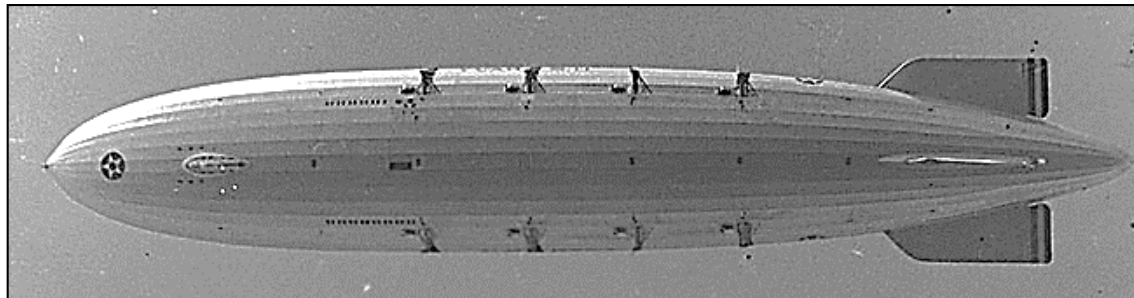
Introduction: UAS Carrier Airship Advantages

UAS carrier airship operational capabilities

- Offer easily re-deployable and re-locatable mobile airborne UAS base
- Provide airspace access for long duration UAS operations
- Loiter at a safe location, but close enough to control, refuel, or replace UAS
- Provide local UAS resource for field commands, ships, or commercial package deliveries from above a city
- Provide self-contained transport of UAS ready for immediate operation
- Can recover other UAS launched from land or sea

Flying Carrier Background

- 1930's airships were developed for deploying scout planes
- USS Macon and USS Akron
 - 25 ton payload
 - Manned scout biplanes
 - Sweep 165,000 sq. mi. in 12 hr.



**Left: USS Macon viewed
from below.**

**Above: USS Macon above
New York City in 1933.**

Flying Carrier Background (cont.)

- **USS Akron and Macon built for long range strategic reconnaissance**
 - Operated 5 Sparrow Hawk planes up to 3 days
 - Planes stored in onboard hangar, launched and recovered by articulated trapeze



Sparrow Hawk engaging USS Macon trapeze



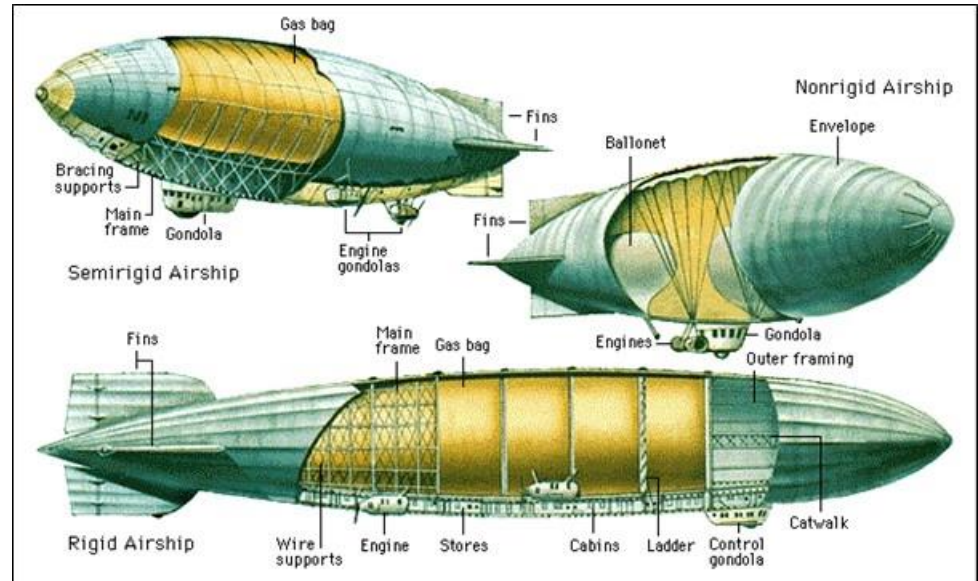
Plane hauled into USS Macon hangar



Model of airplane hangar and trapeze

Modern Airship Types Background

- **Three types: non-rigid, semi-rigid, rigid**
 - Floats by displacing weight of air with LTA gas
- **Two airship classes:**
 - Near-buoyant and “hybrid”
- **Performance:**
 - Max speeds 85 to 95 kt., cruise speeds 40 to 50 kt.
 - Fuel consumption far less than jet with equal payload



Airship types



LMH-1 hybrid, non-rigid



Zeppelin N 07 near-buoyant, semi-rigid

UAS Carrier Airship CONOPS

- **Launch and Recovery**

- Robotic technologies can be used for UAS launch, recovery, and re-launch
- Can accommodate simultaneous launch and recovery operations
- Automated systems means small flight crew (2-4) (could be optionally piloted)
- UAS can be operated by onboard pilots or remotely via data links to airship



Notional UAS Carrier airship with deployed UAS squadron

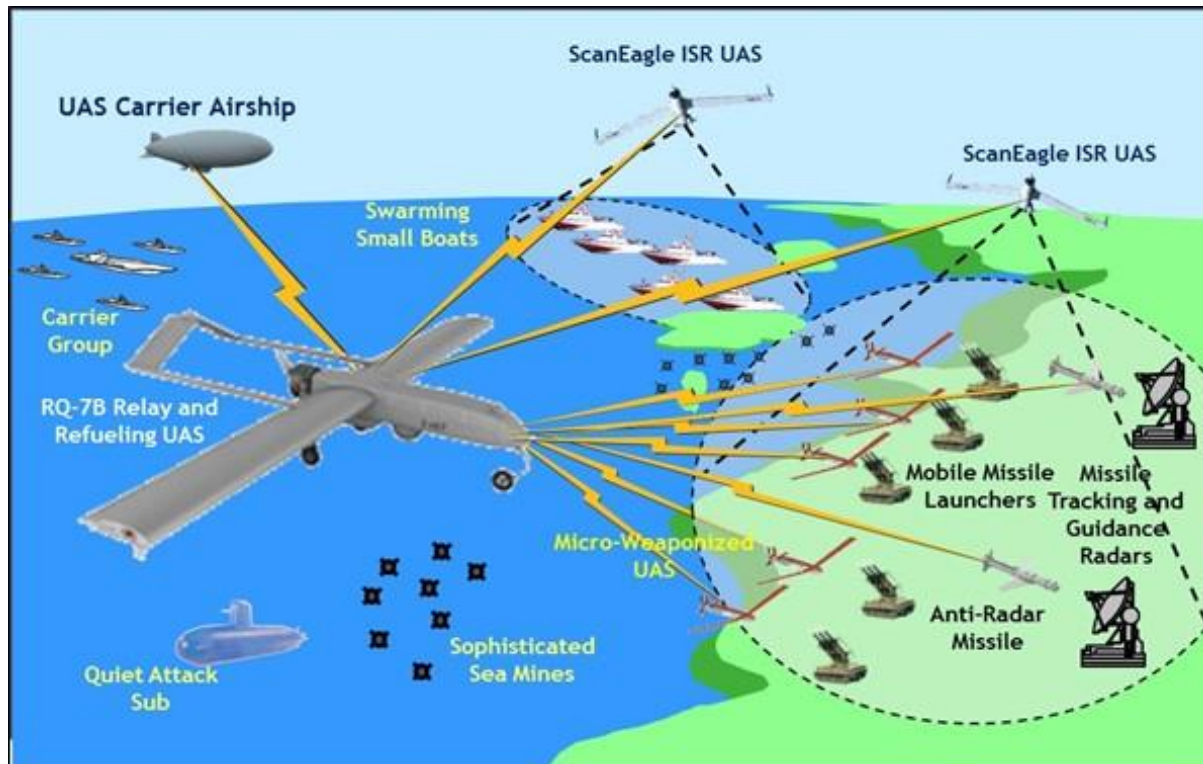


Concept for simultaneous
launch and recovery of UAS

UAS Carrier Airship CONOPS (cont.)

Signal relay UAS operations

- UAS range extendable over-the-horizon (OTH) via signal relay UAS
- Airship hovers at remote location to reduce vulnerability and weather risks



OTH control of various UAS from airship via relay UAS



UAS Carrier Airship CONOPS (cont.)

- **UAS Refueling**

- Modified trailing refueling drogue for UAS
- Robotic airship trapeze recovery and refueling
- Use signal relay aircraft for UAS-to-UAS refueling



Airship trails refueling
drogue for UAS probe

- **Airship Refueling**

- Fuel bladder hoisted from ground or sea
- Optionally piloted “flying fuel tank”
 - Light plane modified to hook onto airship in flight
 - Airplane pumps fuel to airship from onboard tank



UAS-to-UAS in-flight refueling



“Pelican” optionally piloted Cessna 337, O2, Skymaster

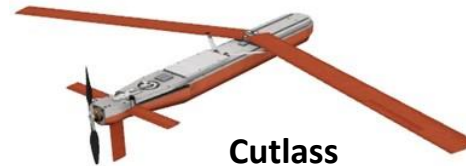


Air-liftable fuel transport bladders

UAS Carrier Airship CONOPS (cont.)

- **Military UAS**

- L3 Cutlass
- Boeing Dominator
- Boeing RQ-21a Blackjack
- Textron Systems RQ-7b Shadow



Cutlass



Dominator



Blackjack



Shadow

- **Payloads:**

- Cameras, miniature synthetic aperture radars (SAR), imaging laser radars (LADARs)

- **Civilian/Commercial UAS**

- Quad/Hex/Octo –copters
- Fixed wing / vectored lift

- **Payloads:**

- Emergency response supplies
- Commercial packages



Hex-rotor
package delivery

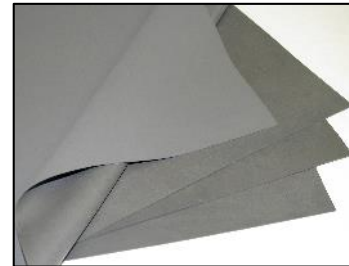


Fixed wing package
delivery UAS

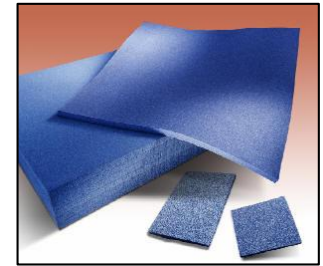
UAS Carrier Airship CONOPS (cont.)

Airship Survivability

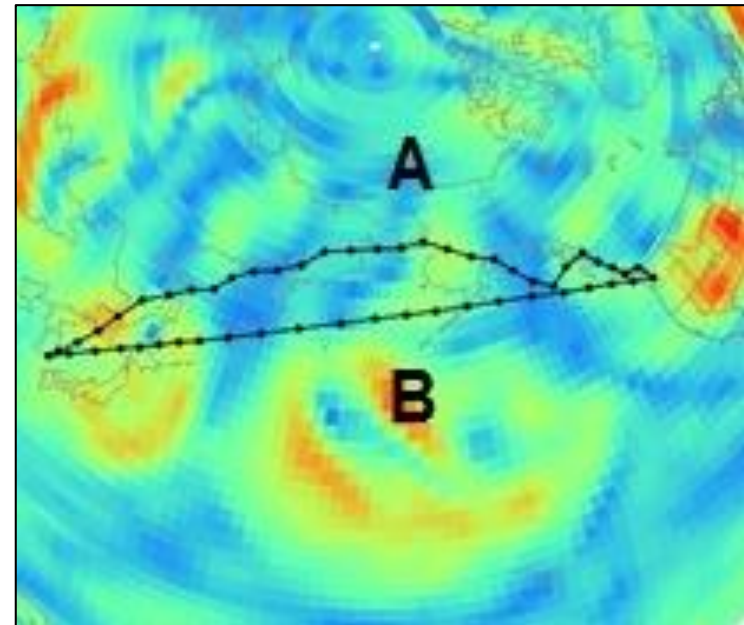
- Invulnerable to sea mines and torpedoes
- Fabric structures are tolerant of small hole damage (low leakage)
- Airship hull, structures, and engines can be treated for visual, RF, and EO/IR stealth characteristics
- Other systems can provide electronic and kinetic self-defense
- Weather-optimized flight route planning enables airship to avoiding damaging weather



RF absorbent fabrics



Radar absorbent foam

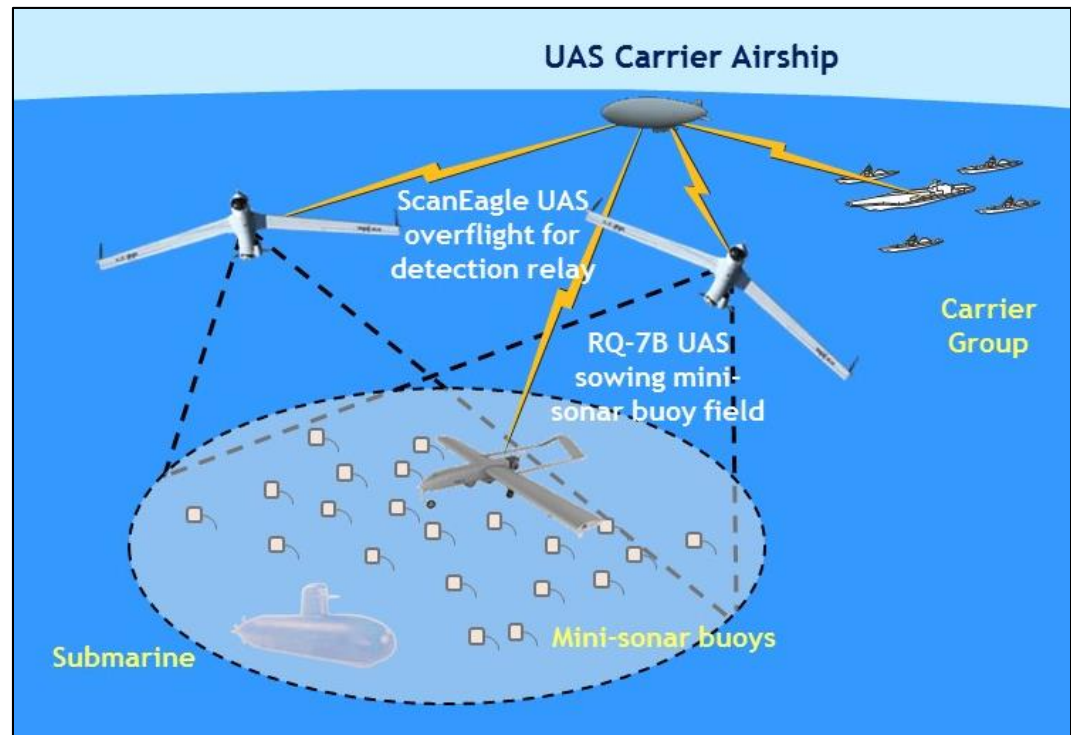


Weather optimized airship route (A) vs Great Circle route (B) between Ft. Lewis and Pusan

Hypothetical UAS Carrier Mission

• Anti-Submarine Warfare (ASW)

- UAS carrier airship positioned at safe stand-off range of 50 – 100 nm, from sub search area at 10,000 to 15,000 ft. MSL
- RQ-7B UAS aircraft “sow” mini-sonar buoys in sea
- ScanEagle UAS maintain overflight relaying detection signals from sonar buoys
- UAS carrier sends UAS to maintain continuously refreshed sonar buoy field and replacement of overflight UAS



UAS Carrier Development Program

- Technology exists to develop medium (10 ton) to large (45 ton) UAS carrier airships
- Staged development would enable investigation and design of all concept components
- Extensive modeling and simulation is needed to investigate and refine airship vehicle, UAS support systems, and operational concepts
- Available manned and unmanned airships can provide sub-scale development of all essential systems and flight test validations



Concept of UAS airship with two ScanEagles attached to recovery platforms



Conclusions

- **UAS carrier airship is the next logical step in the deployment of UAS for military and civilian applications**
 - Provides an operationally flexible airborne UAS operations base
 - Provides UAS range extension via OTH relay UAS and inflight UAS refueling
 - Offers potential as a cost effective means to operate large groups of UAS in coordinated tasks
 - Current technologies are in hand to develop the UAS carrier airship and its UAS support systems



National Aeronautics and
Space Administration



Questions?