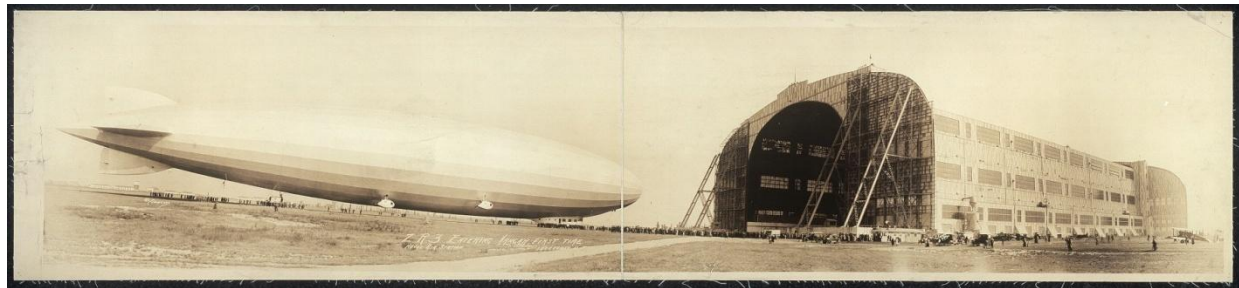


Building Large Airship Hangars in Canada

Engineering Considerations

History of Hangar Structures

- In 1909, a French airplane pilot crash landed and rolled into a farmer's cattle pen
 - He decided to set up shop in this unused shed, later ordering a number of these sheds for further use
- The word hangar comes from a northern French dialect, and means "cattle pen"



Zeppelin ZR3 approaching Hangar (Naval Air Station, Lakehurst, N.J)

History of Hangar Structures

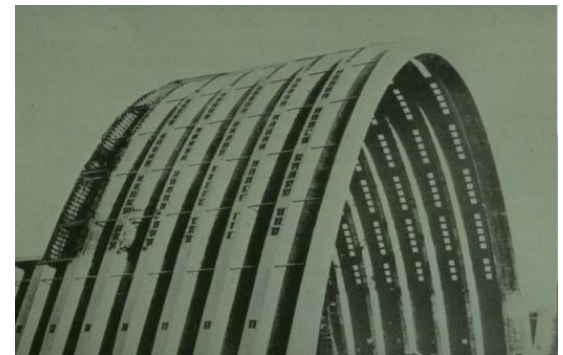
- A limited number of the over 100 airship hangars built in 19 countries survive today and documentation related to their construction is scarce
- With the reinvention of the airship, the hangar needs to follow suit
 - Borrowing cues from the past and taking advantage of contemporary design and construction techniques

History of Hangar Structures

- One of the first zeppelin sheds in Germany (1909) was a 600 ft x 150 ft x 66 ft steel-lattice structure with light cladding
- 1920s saw the construction of parabolic reinforced concrete hangars
 - Designed by the pioneer of prestressed concrete, Eugene Freyssinet



Construction of Former Hangar at
Orly, France



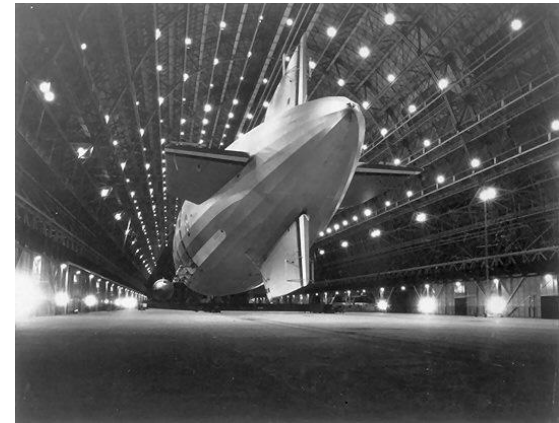
Former Hangar at Orly, France

Airship Hangars

- “Hangar One” in California is a famous North American hangar that survives today
 - Over 1000 ft long and 308 ft wide



Hangar One , NASA Ames Research Center
Moffett Field, California



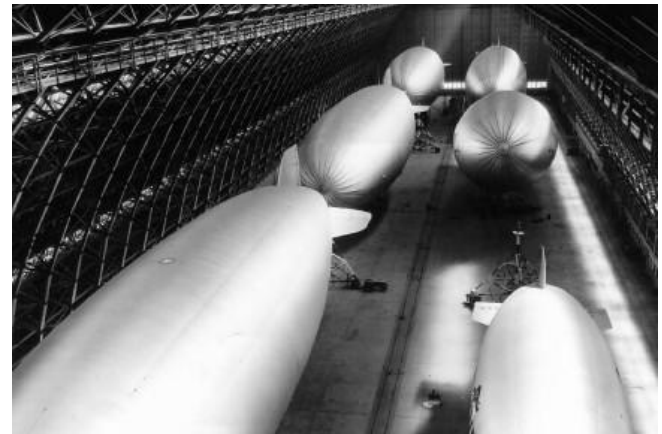
USS Macon inside “Hangar One” circa 1933

Airship Hangars

- Another famous group of hangars in California are at Tustin
 - Over 1000 ft long, 300 ft wide and 178 ft high
 - All-wood design... war time rationing. Steel construction of large structures common practice since the early 20th century



Tustin Hangar



6 airships inside former Marine Corps Air Station in Tustin, CA

Repurposing of Hangars

After programs were shut down or certain airship proponents encountered set backs, hangars have been used for or converted to:

- Housing for other aircraft (planes, helicopters)
- R&D – Lockheed used NASA “Hangar One” for construction and assembly of the nation's first nuclear stage rocket engine
- Storage/warehousing
- Landmarks, Museums
- Recreational centers
 - Former CargoLifter airship hangar (Brandenburg, Germany) is now an artificial tropical resort called Tropical Islands Resort



Hangar/Landmark at Farnborough, UK
(Photo Credit: Simon Taylor)



Tropical Islands Resort

Resurgence

- We have seen the golden age of the airship and hangar, followed by an apparent hiatus and loss/repurposing of hangars
- We are now seeing hangars restored to their original purpose
 - NASA is hard at work on a plan to restore Hangar One within the next year in order to return it to "its original purpose."
 - Goodyear Airdock was purchased by Lockheed Martin and is being used for manufacture of a new cargo ship
- As onlookers FWS observed the momentum going and wishes to be a part of the action moving forward

FWS Company Profile

- Design-build construction company
 - FWS Group has built over 100 slip form concrete structures throughout North America
 - Principles of precision, professionalism, efficiency and quality are all hallmarks of our success
- Fully integrated FWS approach to construction and development unifies owner, consultants and contractor(s) into a results-oriented building team
- Excited by the opportunity to adapt our techniques to the airship industry

Conceptual Hangar Design Considerations

Design Principles

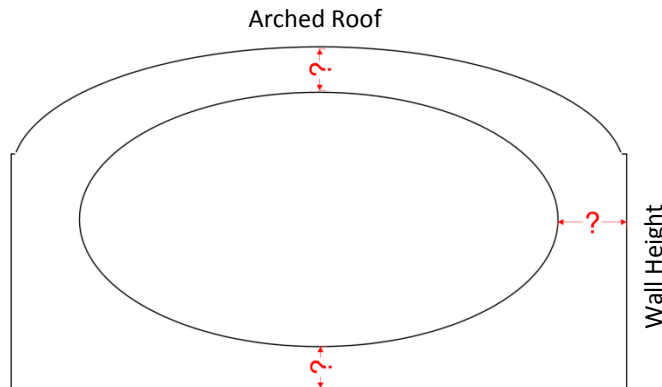
- There have been many diverse approaches to hangar construction
- FWS' design and construction methodology is informed by the past but based on construction techniques that FWS has practiced for years
 - Economy
 - Reliability
 - Simple operation
 - Adaptability to various airship shapes
 - Ability to cope with environmental conditions
 - Dynamic open space (free spans)
- Simplicity
- Constructability
- Lightness

Hangar Function

- Manufacturing
 - A production hangar serves as a template and must be viewed as integral to the overall design approach of the airship itself
- Operations
 - “Dry dock” – inspections, maintenance, inflation, fueling
 - Every airship must spend at least 1 week a year in a hangar
- Manufacturing & Operations

Dimensions and Geometry

- The overall dimensions will be governed by the airship(s) and what clearances are required
- Depending on the airship, the envelope could be in the range of:
 - 350 – 600 ft LONG
 - 250 – 340 ft WIDE
 - 150 – 250 ft HIGH
- A Canadian football field is 450 ft LONG x 195 ft WIDE



Foundation & Floor

- Due to large footprint, significant soil variability is expected
- Settlement and lack of stability may lead to operational issues and compromise integrity and lifespan of hangar
- Foundation could be pile or raft style
 - Pile foundation would be most likely as soil variability is easier to accommodate with piles
- Concrete slab on grade floor (or minimal or no floor at all?)
 - Cast in sections, staged to accommodate work load (according to finishing criteria)
 - Cast after roof is on to make finishing easier with shelter from elements

Hangar Walls

- Steel or concrete can be used for hangar walls
 - Must take systems approach to overall construction in determining how choice of wall material impacts cost, schedule, material availability, etc.
- Steel could be very labor intensive and require larger cranes
- Concrete enables the use of an important construction method that FWS has perfected, Slip Forming

“Slip form” refers to the moving form the concrete is poured into, which moves along the project as the previously poured concrete hardens behind it



Cylindrical slip form concrete tank





“Slip form”

Hangar Walls – *Slip Form Technique*

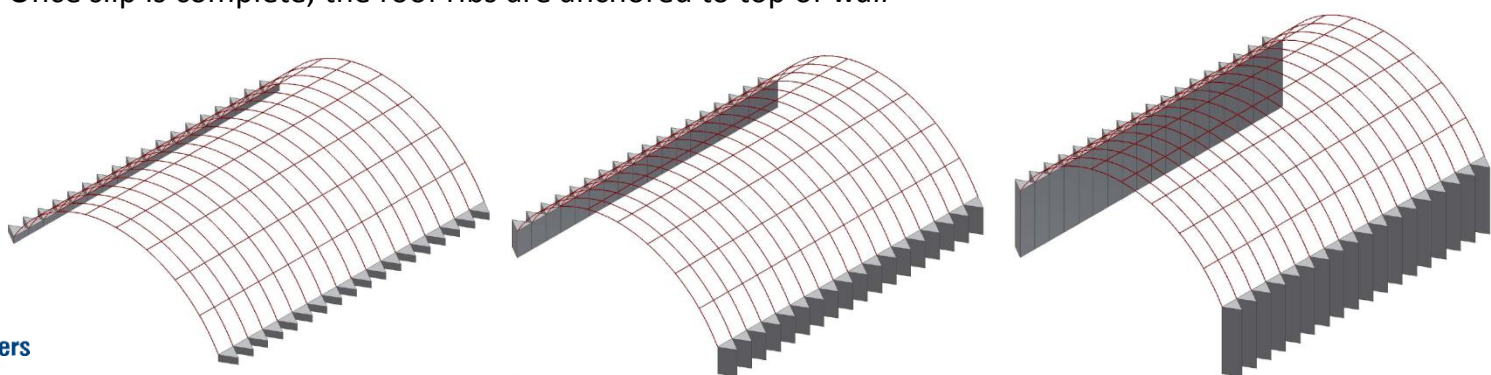
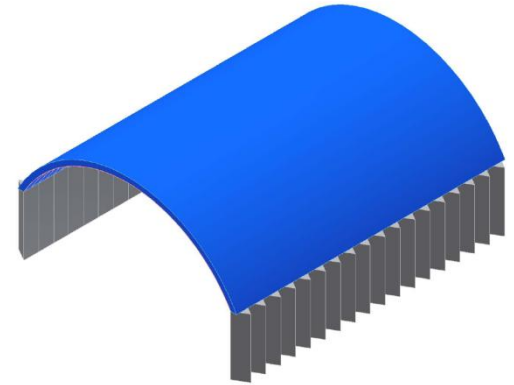
- Allows you flexibility in forming to maximize stability relative to thrust of roof arch
- Reduce dependency on construction cranes
 - Smaller craning equipment

Hangar Walls - Shapes

- Corrugation 
 - Provides stability to take thrust of arch because of geometric shape
 - Allows you to take load down to foundation (take thrust from roof to foundation effectively)
- Pilaster wall 
 - Also can provide for stability
- Economics will determine wall shape/style

Roof

- Arch is compatible with inherent shape of airships
- Minimizes roof height & wall height
- Less dead air space
- Roof skin
 - Material that can resist cold & snow load
 - May be traditional steel cladding or composite fabric (Kevlar, etc.)
- Roof arch ribs are raised as slip progresses
 - Roof arch would be part of slip form and move during pour
 - Once slip is complete, the roof ribs are anchored to top of wall



Doors

- Many door concepts have been explored:
 - No doors, barn doors, segmented doors, “orange peel” doors, inflatable doors, doors on rails, ...
- Door system to be self supporting in order to reduce lateral loading on main hangar structure (roof lightness is paramount design consideration)
- Doors at both ends? One end only?

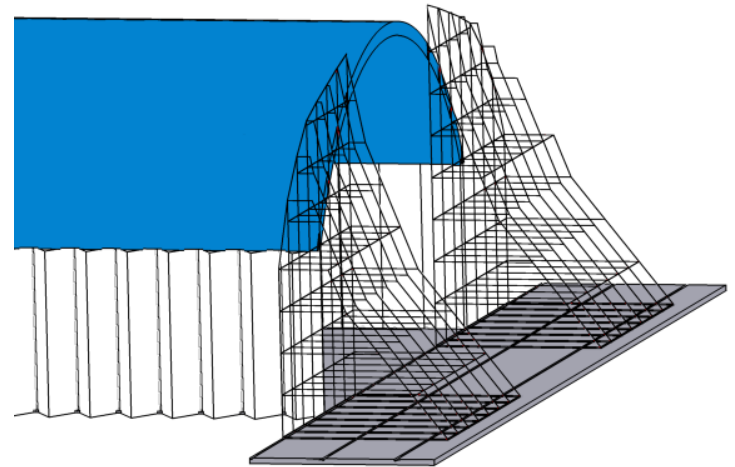


Doors

- Door systems
 - Door tracks/rails
 - Door mass strongly directly and indirectly influences the hangar costs

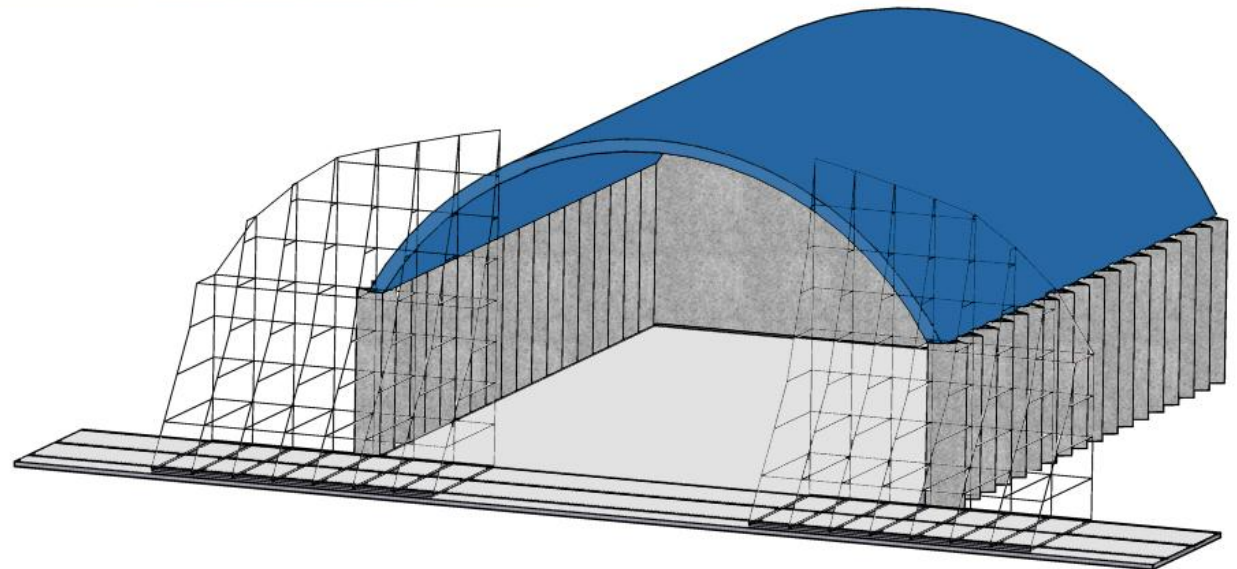
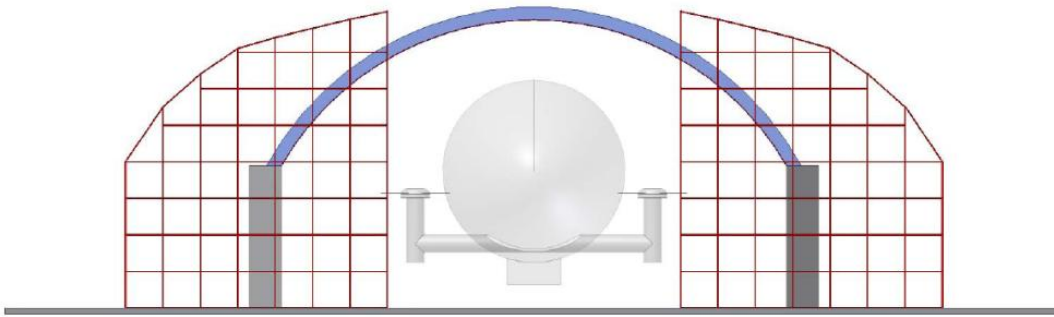


Hangar Doors at Cardington



FWS Door Concept

Design Concept



Safety, HVAC, Lighting

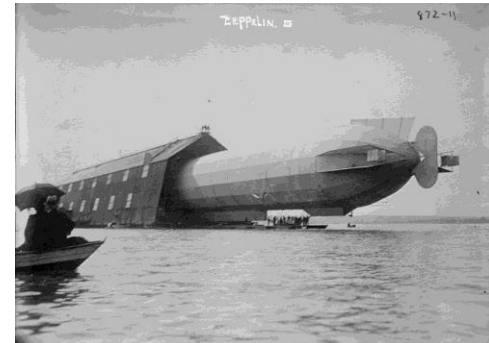
- Fire detection, protection & suppression
- HVAC
 - Does envelope require heating?
 - CargoLifter hangar had heating system and the air space was 5.2 million cubic metres!
 - Under floor/in-floor heating, radiant panels, geothermal
- Lighting considerations

Ancillary Systems

- Tug
 - Tug system/rail integrated with floor slab
- Mooring pad & mast
- Crane inside for moving parts about, servicing
- Lift gas generation and purification system
- Piping systems for lift gas & fueling

Call for Design Criteria from Stakeholders

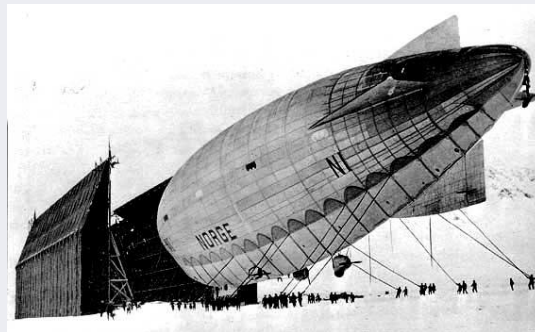
- Further input is desired from stakeholders to refine preliminary designs
- Input required on details such as:
 - The importance of hangar orientation relative to prevailing winds?
 - Do we need to heat the hangar?
- FWS would be pleased to discuss design concepts with interested parties



Zeppelin, Lake Constance

Conclusion

- “There is no egg without an incubator”, the hangar plays a vital role in the airship industry
- It is exciting to witness new developments in the airship industry
- FWS looks forward to determining how we may facilitate the resurgence of the airship



Airships to the arctic! Preparing for North Pole flight

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