SPACE TECH EXPO
DESIGN • BUILD • TEST

Towed Glider Air Launch System

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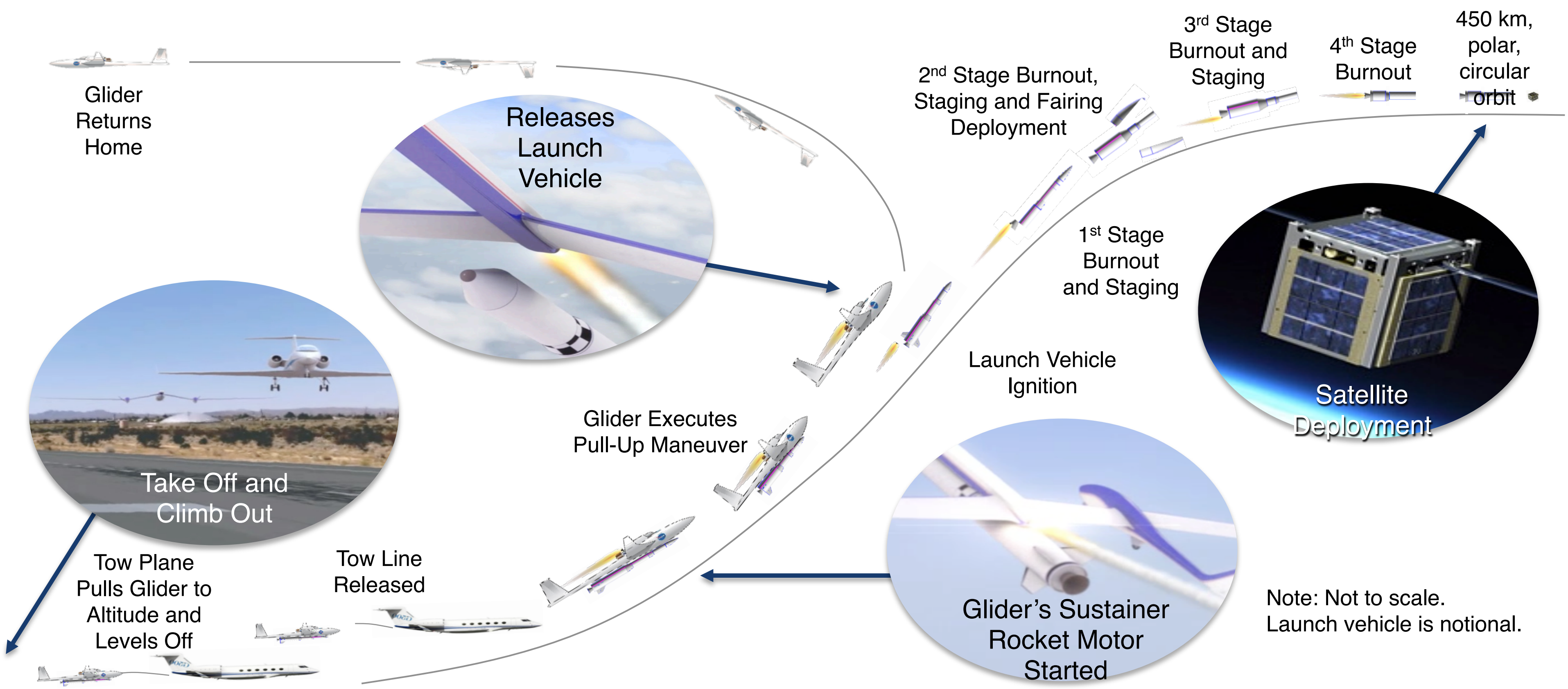
TOWED GLIDER LAUNCH PLATFORM ANIMATION

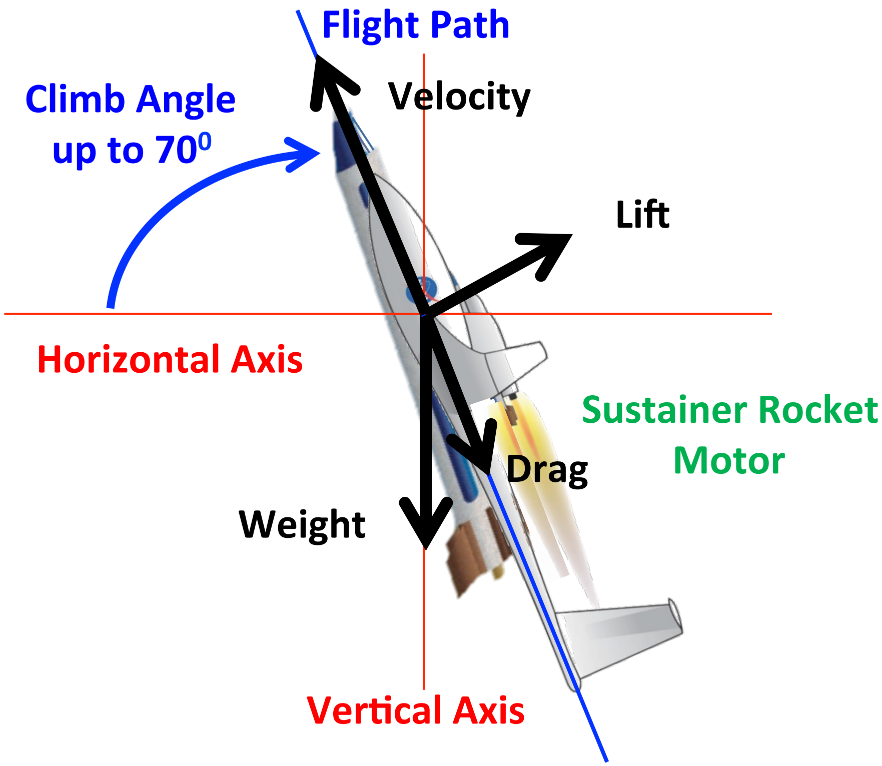
A remotely-piloted glider, towed by a modified cargo/passenger jet, releasing a launch vehicle with payload at 48K', M=0.75, up to a 70^0 flight path angle, safely & effectively.

TOWED GLIDER LAUNCH PLATFORM CONOPS



Note: Not to scale.
Launch vehicle is notional.

Sustainer Rocket Motor



Location: Mounted on top of the glider

Purpose: Provides variable thrust on demand to change the Glider and LV orientation from horizontal to nearly vertical

Features:

- Restartable
- Throttleable from ~15% to 100%
- Controllable
- Increases Glider fly-back range

Profile: Start horizontal, idle sustainer motor, begin pull-up towards 70^0 climb, use sustainer motor variable thrust to maintain constant airspeed during climb, stabilize at 70^0 then release LV

The sustainer motor provides the energy to go from horizontal to nearly vertical so the LV is optimally oriented for launch

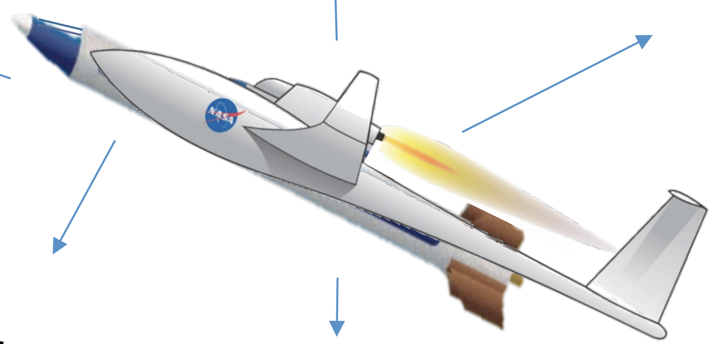
Glider Design Creates Trade Space

Next Generation: Towed Glider

Remote piloting eliminates need for human rating for the LV and the glider

Glider can be sized to allow growth for future desired payloads

Payload max size virtually unconstrained due to glider geometry and ability to build to suit



Minimal separation analysis required for un-crewed aircraft

Open center wing design minimizes LV clearance issue

Glider simple design is low maintenance

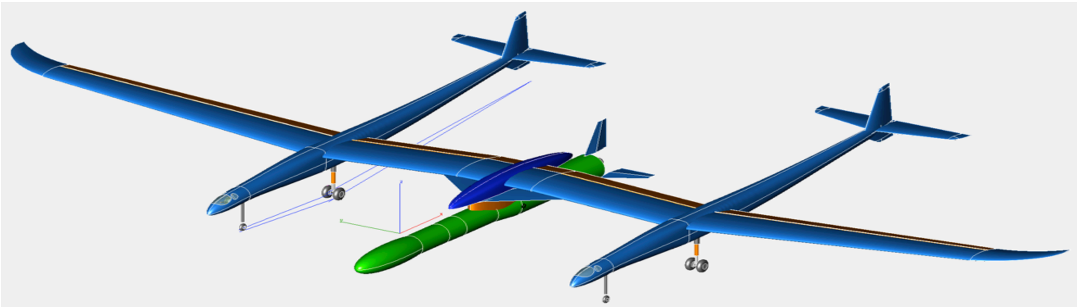
Towed Glider flexibility ensures design success

Why Towed Glider?

- Performance:
  - Pull-up maneuver provides a 30% increase in payload performance to orbit over current air-launch approaches, up to 70% increase over ground launch
- Geometry:
  - Can lift significantly larger payloads to altitude vs modifying a same size, direct carry, "conventional" aircraft for external carriage
- Cost: Less expensive to build, operate, and maintain than a one-of-a-kind, custom carry aircraft
  - Simple glider, devoid of expensive, complex systems
    - No hydraulics, fuel system, engines, life support, egress systems
  - Leverages the advantages of air-launching
    - No dependence on critical ground based launch facilities/assets
- Safety: Unmanned glider eliminates aircrew concerns for carrying LV
  - LV doesn't have to be human-rated (blast proximity), nor does the glider
- Technology: No new technologies required, just an integration of existing, proven technologies

Independent Concept Validation Studies

- NASA contracted with three separate entities in 2012 to study and assess the viability of the Towed Glider Air Launch System Concept
  - Georgia Tech University
  - SAS/Rutan Designs
  - Morgan Aircraft Co.



Design Carry Efficiency: 1.85

- All three studies concluded that:
  - The concept is viable;
  - It offers significant improvements in efficiency, performance, and cost, over current state of the art air launch methods.

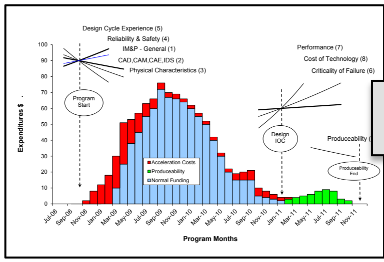
*The studies showed the concept is do-able…**next step is the Proof of Concept***

Aerospace Corp. Business Case Analysis

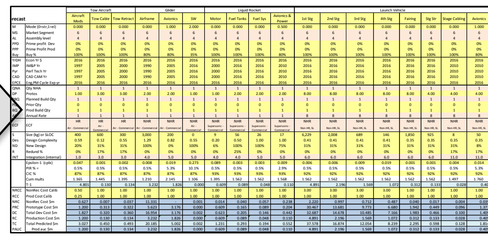
- Aerospace Corp. is currently performing a study of TGALS to:
  - Estimate the costs associated with the development, integration, and test of major TGALS components:
    - Glider
    - Glider sustainer motor
    - Tow plane modifications
    - Launch Vehicle modifications
    - System operations costs
  - Develop projections for potential TGALS launch rates under several different scenarios
  - Forecast TGALS financial performance within these scenarios, using both a traditional government acquisition scheme as well as a private-public partnership mechanism proposed by AFRC, including the following metrics:
    - Cash flow projections
    - Return on Investment (ROI)
    - Payback period
    - Net Present Value
    - Operating Margins

Business Case Analysis (BCA) – Modeling Approach

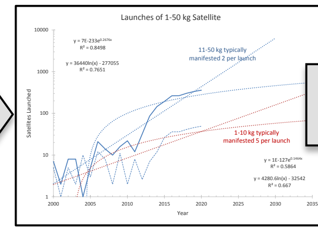
BCA modeling predicts technology, industrial capability, development and acquisition cost, market size, capture rates, financials, uncertainty, and utility functions resulting in decision frameworks



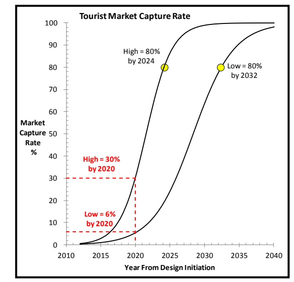
Technology forecasting
Industry capability assessment



Alternative payload configurations
Specific system components
Design difficulty and inherited development

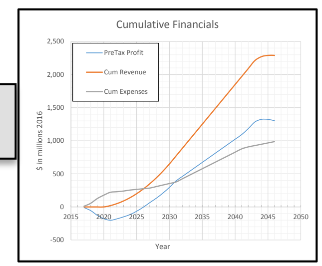


Market forecasting
Price demand elasticity
Competition effects
Profit mark-up predictions

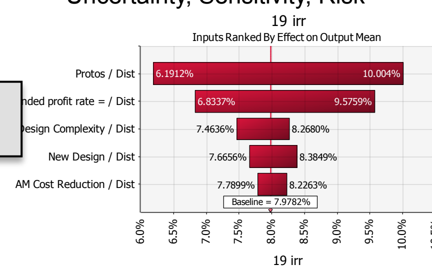


Competitive assessment
Profit application feasibility
Capture rate prediction

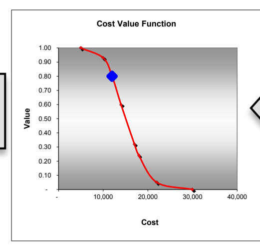
Profit/Loss, Breakeven, ROI, NPV



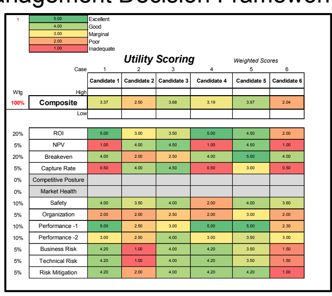
Uncertainty, Sensitivity, Risk



Value Utilities



Management Decision Framework



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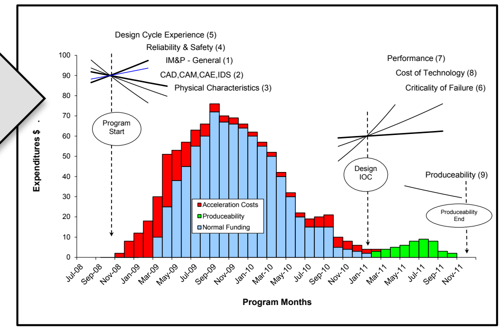
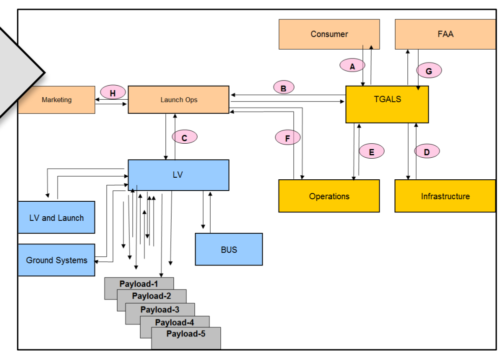
Cost and Revenue Estimate Major Components and Features

- Modeling of all major system components to reflect the acquisition and operations cost accurately
- Technology forecasting (methods, processes, computer aided design and manufacturing, etc.)
- Integration complexity
- Costs and reliability versus flight test program quality
- Operations model that depreciates system components, maintains, refurbishes and replaces within reasonable periods
- Organization complexity model reflecting system components and organizational layering
- Financial model reflects competitive pricing and investor returns
- Dashboard that compiles success metrics for technical and business factors, a control dashboard and system composite metrics

Industrial Base Capabilities Model



Organization Complexity Model



Business Case Analysis (BCA) Major Assumptions

- General
  - Program development is initiated in calendar year 2017
  - All cost estimates in FY 2016 $m
  - Market assessments and financial returns include operations to 2040
  - Profit margins charged are reflective of marketplace competitiveness
  - A reserve of 20% is included in provider launch and fixed costs

- Flight Providers
  - New launch providers = 11
  - Survival rate for new providers = 70 %
  - Total providers = 9 (competitive by payload class with multiple manifesting)
  - Tax rate = 35%

- Flight Vehicle Operations
  - No disruption due to catastrophic failures is included

Fixed Cost (annual)
TOW AC annual depreciation
Glider annual depreciation
Hanger, Office and Facilities
Management and Procurement
Administrative
Engineering
Engineering Support
Marketing and Advertising
Ground crew
Tow Flight crew
Software Maintenance
Flight Ops
Tow AC Operations
Liq Rkt Consumables
Liq Rkt Refurb per flight
Liq Rkt Replacements
Glider Maintenance
Launch Vehicle
Payload Integration
Grd Station TT&C & Space Net
C-17 Ferries
Airport Fees
Liability Insurance

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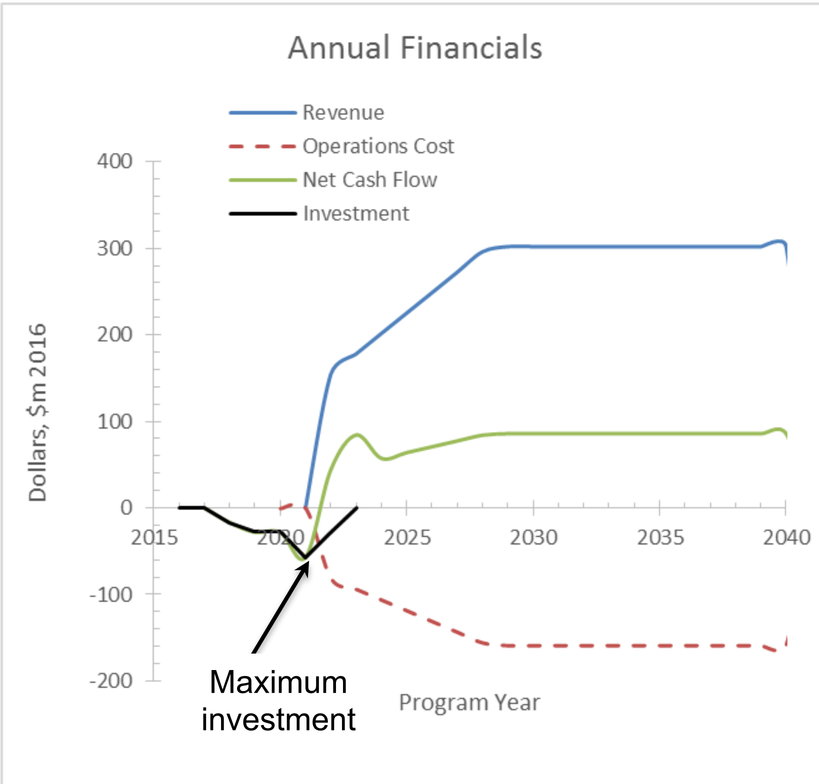
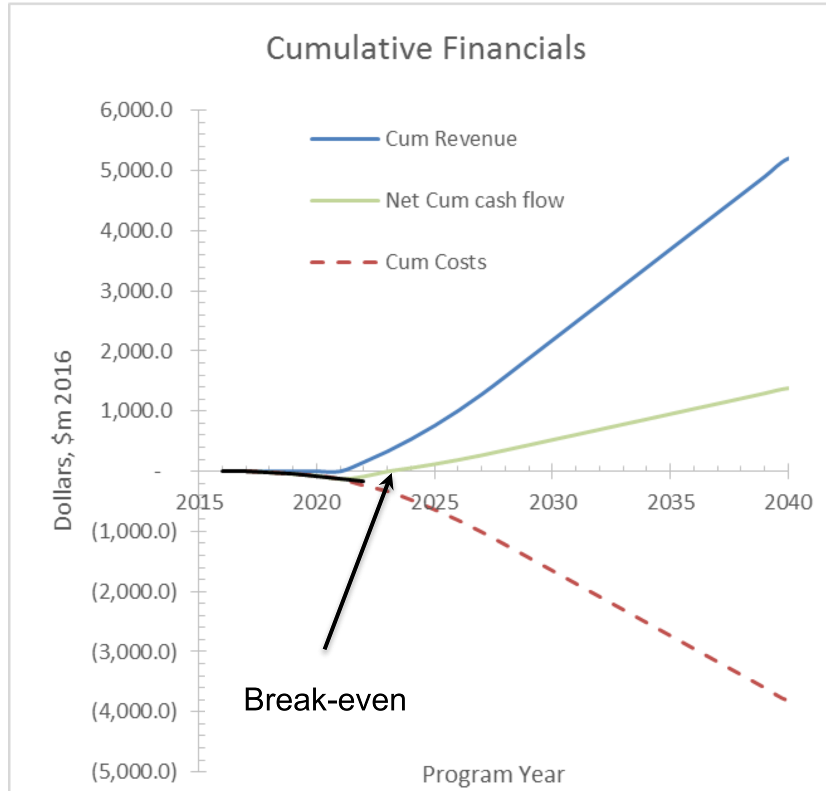
Cost and Revenue Summary – Annual and Cumulative





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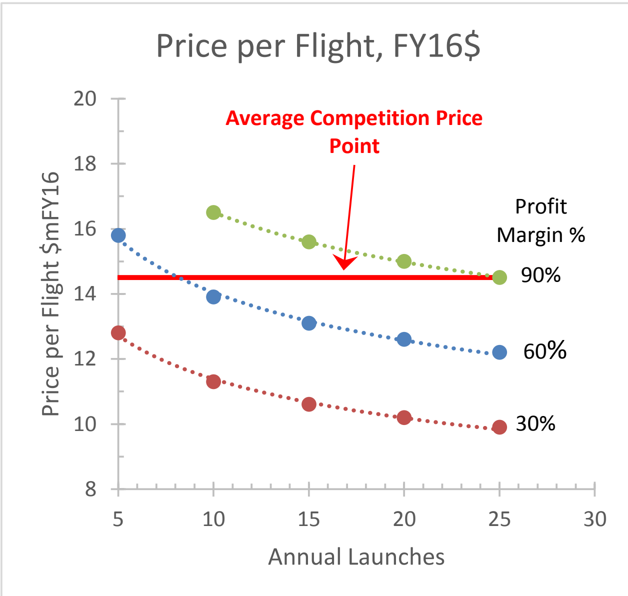
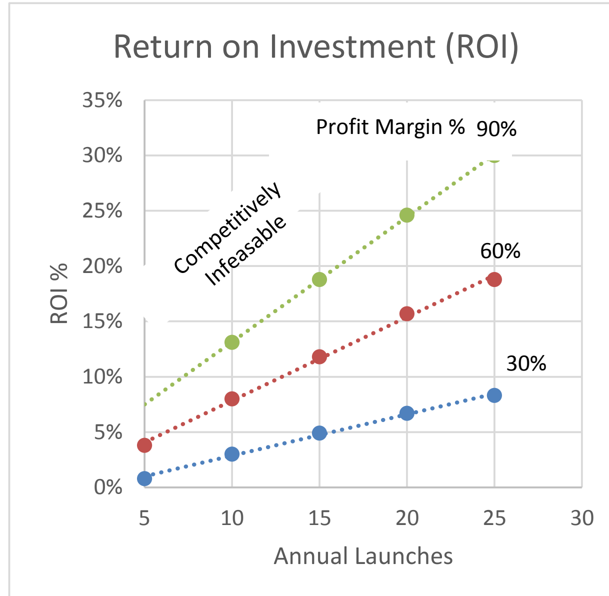
Sensitivity Analysis





- With an investment partnership, the price per flight allows reasonable profit margins
- However Return On Investment (ROI) requires a profit margin per launch of 50-70% and annual launch rates above 12-15 to achieve a reasonable ROI of 10-22%
- A reserve of 20% is included in provider launch and fixed costs

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Study Observations, Conclusions, and Recommendations

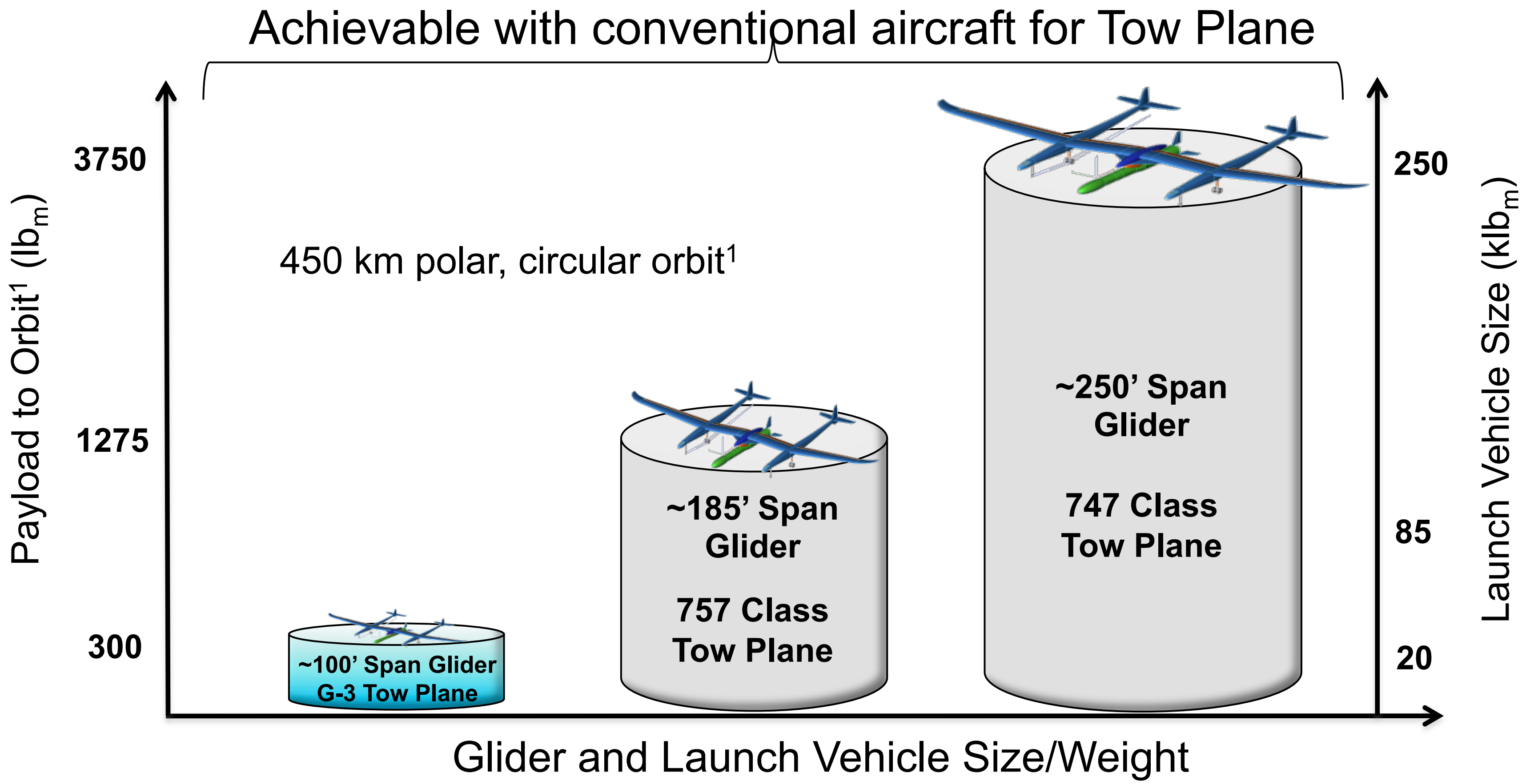
- # Observations
  - Detailed modeling is important to differentiate design approaches
  - Multiple payload capacity capability for a single provider is difficult to characterize in the market model due to self competing

- # Market Analysis
  - Experienced and skilled market forecasting can miss actual launch rates by a large margin
  - Multiple manifesting and constellations complicate launch vehicle market forecasting
  - Competition price point determination is important in determining profit margin

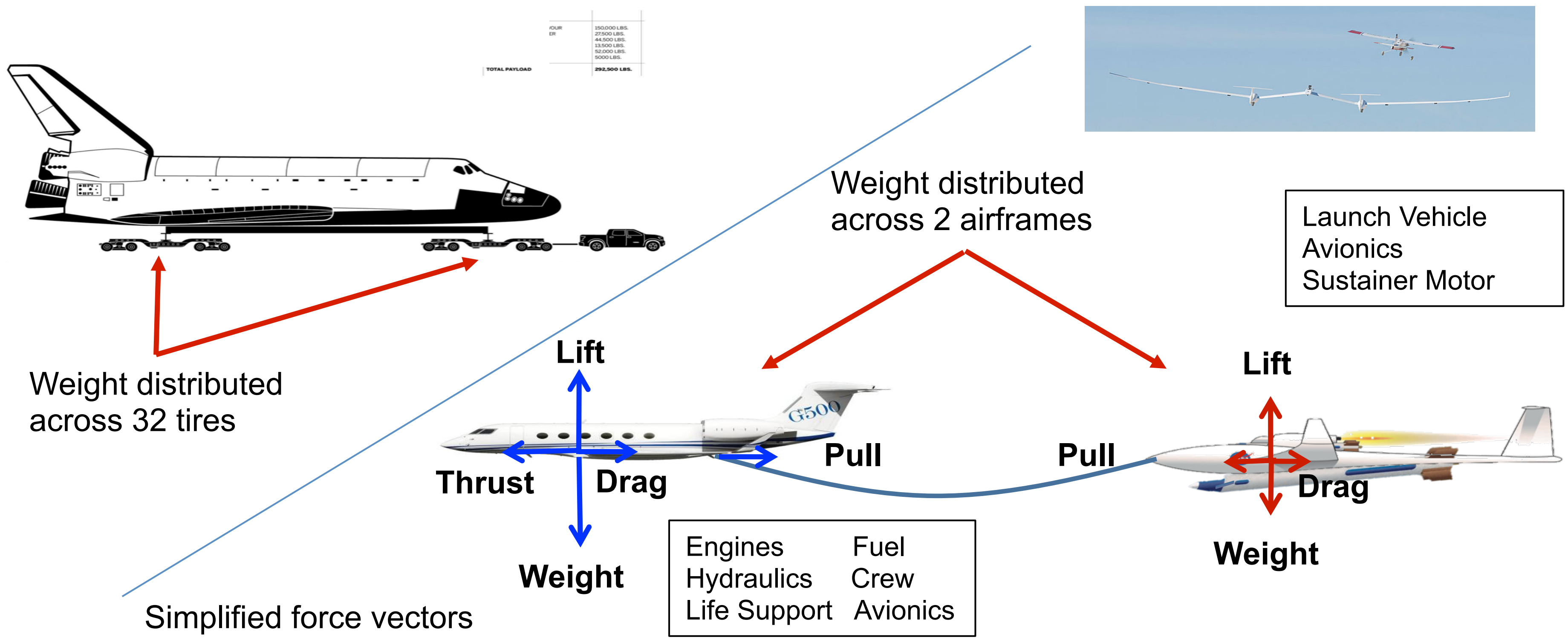
- # Results
  - The model is aiding in determining profitable approach, design, and heritage constraints
  - As usual flight rate is a large driver
  - Projected costs for the towed concept have the potential to be competitive
  - In an increasing market a reasonable ROI is possible

Questions?

Towed Glider Technology is Scalable



Its all about Weight Distribution…



Towing, on the ground, or in the air, is more efficient for moving large, heavy objects

Background: F-106 Tow Experiment (1997)