Towed Glider Air Launch System

Gerald D. (Jerry) Budd, Project Manager
NASA Armstrong Flight Research Center, Edwards, CA
661-276-3377 (office)
661-607-1483 (cell)
jerry.budd@nasa.gov

Darryl W. Webb, Senior Project Leader
Economic Market & Analysis Center
The Aerospace Corporation, El Segundo, CA
310-336-2456 (office)
darryl.w.webb@aero.org
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° flight path angle, safely & effectively.
Towed Glider Launch Platform CONOPS

- Glider Returns Home
- Take Off and Climb Out
- Tow Plane Pulls Glider to Altitude and Levels Off
- Tow Line Released
- Launch Vehicle Ignition
- 1st Stage Burnout and Staging
- 2nd Stage Burnout, Staging and Fairing Deployment
- 3rd Stage Burnout and Staging
- 4th Stage Burnout
- Glider’s Sustainer Rocket Motor Started
- Satellite Deployment
- 450 km, polar, circular orbit

Note: Not to scale. Launch vehicle is notional.
The sustainer motor provides the energy to go from horizontal to nearly vertical so the LV is optimally oriented for launch.

**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° climb, use sustainer motor variable thrust to maintain constant airspeed during climb, stabilize at 70° then release LV.
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.
- 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.
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
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

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<th>Fixed Cost (annual)</th>
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Cost and Revenue Summary – Annual and Cumulative

- **Annual Financials**
  - Revenue
  - Operations Cost
  - Net Cash Flow
  - Investment

- **Cumulative Financials**
  - Cum Revenue
  - Net Cum cash flow
  - Cum Costs

- **Maximum investment**

- **Break-even**
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
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

Achievable with conventional aircraft for Tow Plane

Payload to Orbit (lbm):
- ~100' Span Glider
- ~185' Span Glider
- ~250' Span Glider

Launch Vehicle Size (klb):
- 300
- 3750
- 250

Glider and Launch Vehicle Size/Weight:
- 757 Class Tow Plane
- 747 Class Tow Plane

450 km polar, circular orbit

TGALS – Towed Glider Air Launch System

NASA Space Technology Mission Directorate 2016
It's 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)