S4A – Boost Glider Duration

vNARCON 2022

Chris Flanigan

NAR 17540

Agenda

- Overview, history, and current rules
- Design considerations
  - Boost, glide, recovery
- Details of a slide wing model
- Details of a scissors/flop model
- Models from other countries
- Ancillary issues
- Q & A

OVERVIEW, HISTORY, AND CURRENT RULES

Current S4 Is Equivalent to NAR R/G

- **S4 is "boost glider duration competition"**
  - **Space model competition, class 4**
- **Originally, S4 was similar to NAR B/G event**
  - **Pop pods, etc.**
- **Awkward innovation was internally-carried tiny gliders**
  - **Glider ejected at apogee**
  - **Very difficult to see for timing, even with binoculars**
  - **Very difficult to tell if the tiny glider was actually gliding or just drifting/tumbling with the wind**
- **S4 rules changed to eliminate ejectable items**
  - **Everything that goes up, has to come back gliding**
  - **Equivalent to NAR R/G event**

(continued)

S4 Semi-Recent Rule Changes

- **S4 had a minimum mass requirement, but now eliminated**
  - Leftover from trying to address the tiny glider issue
- **There is still a maximum mass rule (60 gr for S4A)**
  - Why?
  - Never measured at model check-in
- **S4 models may use radio control for dethermalizer**
  - Similar to rules for Free Flight models
  - Model must be free flight only during standard portion of glide
  - RC safer than slow-burn fuses
    - Minimal danger from RC nichrome wire release
  - Mass of RC is a challenge (receiver, battery)

S4 Motor Impulse Classes

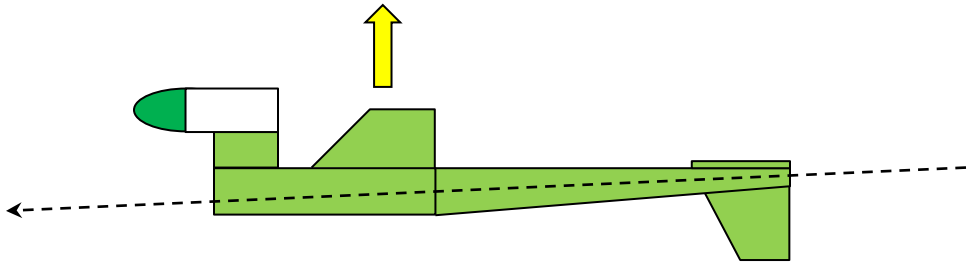
- **S4 has range of motor impulse events …**
  - **A, B, C, D, E, F**
- **… but S4A is the only event typically flown**
  - **Flown at continental and world championships**
  - **FAI medal for best annual performance in S4A**
    - **But not S4B, or S4C, etc.**
  - **Big motivation to fly S4A, little motivation for other impulses**
- **Current trend is to limit impulse to 1/2A**
  - **S4A covers 0-2.5 N-s**
  - **S4A requires large field, large recovery teams, lots of lost models**
  - **1/2A helps address these issues**
    - **Still very competitive and maybe even more challenging!**

S4 Rules Summary

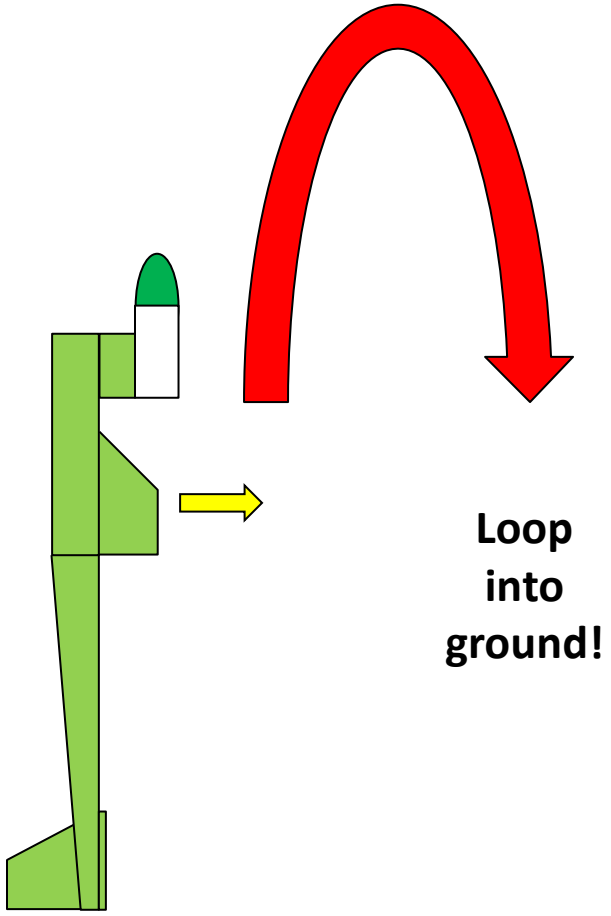
- Must ascend vertically (within 60° cone)
  - Cannot use lifting surfaces during ascent (e.g., Jetex models)
- Must descend gliding, nothing ejected/separated
  - Must enter “stable glide” within 30 seconds, or DQ
- Three standard rounds
  - 180 second max per round
  - Two models allowed for three flights
- If tie after three rounds, one flyoff round with 300 sec max
  - One additional model allowed
- If still tied, final flyoff round with unlimited time
- Models do not need to be recovered/returned, but…
  - 2 models for 3 standard rounds
  - 1 more model for up to 2 flyoff rounds

DESIGN CONSIDERATIONS

Fixed Geometry Glider Will Not Work* for S4



Trimmed for glide



- **Must have change(s) between boost and glide**
  - **Geometry**
  - **Control surface settings**
  - **Mass**
  - **Combination**

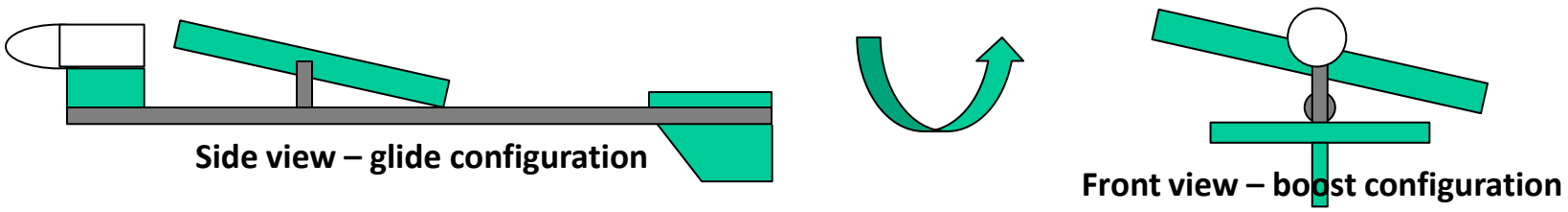
https://www.nar.org/wp-content/uploads/2021/08/No-Moving-Parts-Rocket-Gliders-Vinyard-NARAM-63.pdf

Wide Variety of S4 Design Options

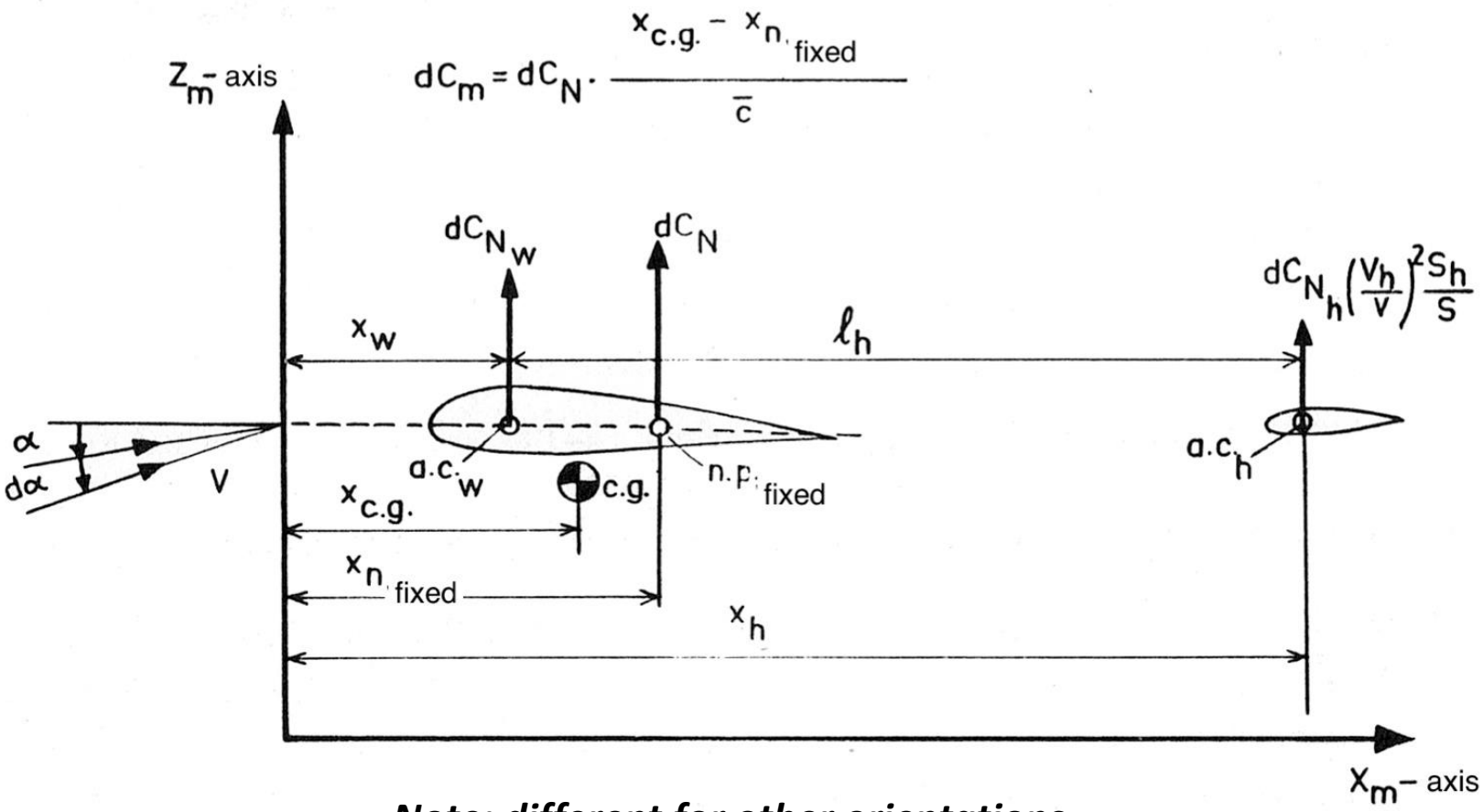
- Pop-up elevator
- Pop-down canard
- Slide pod, motor shift
- Swing wing
- Adjustable wing flaps
  - "Hummingbird" (Parks) derivatives
- Slide wing (partial travel, full travel)
- Flop wing
- Scissors wing
- Combinations
  - Slide/flop wing, slide wing w/pop-up elevator, slide wing w/curved fuselage
  - Scissors/flop

Must Have Positive Transition to Glide

- **Must have correct pitch stability (see next slide)**
  - **Glider must pull out of a dive, from any orientation**
- **Typically achieved by incidence between the wing and horizontal stabilizer**
  - **Horizontal stabilizer or elevator at negative incidence**
  - **Wing at positive incidence**
- **For a scissors wing, wing positive incidence for glide "rotates" in boost configuration**
  - **Easy to make scissors (or scissors/flop) models boost straight**



Calculation of Longitudinal Stability
(horizontal glide orientation)



Note: different for other orientations

https://aviation.stackexchange.com/questions/47306/does-static-longitudinal-stability-require-download-on-the-tail

Incidence Effects Must Be Minimized for Boost

- **Wing/tail incidence causes boost problems**
  - Tendency to loop, even loop-into-ground
- **Solutions to suppress incidence effects during boost**
  - Slide wing
    - Aft wing location significantly reduces pitch moment arm
  - Pop-up elevator or adjustable wing flaps
    - Hold down during boost, release for glide
  - Scissors rotation
    - Wing incidence “rotates” out of pitch plane
- **Note: need large incidence to assure transition**
  - ~2-3 degrees for slide wing model
  - ~3-5 degrees for scissors/flop model

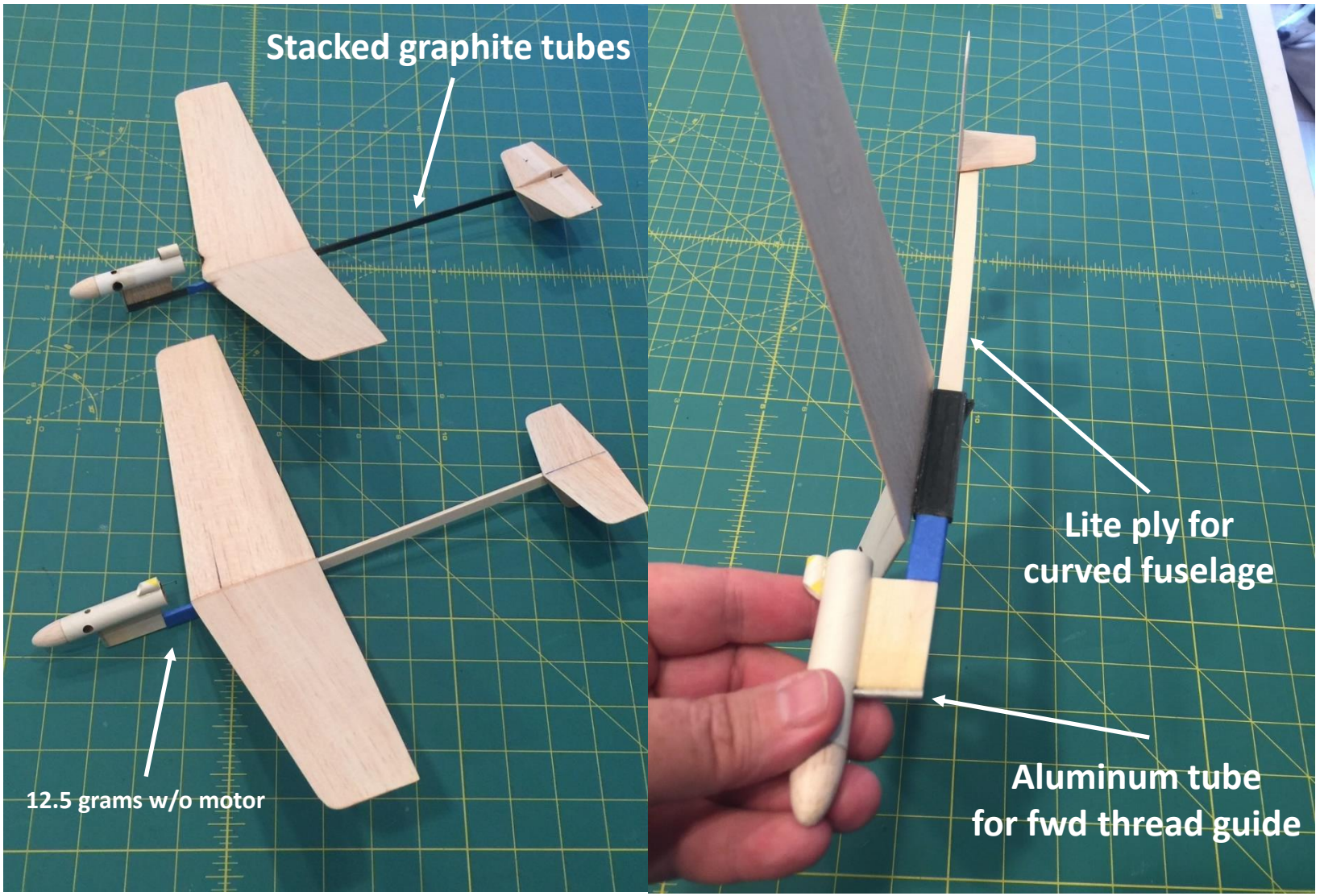
Recovery Is Very Important for Multi-Round

- 2 models to make 3 flights
  - Must get at least one model back to make three flights
- Add bright colors or markings to the model
  - Something to stand out in a field of grass (or sand, or…)
- Sharpies and similar
- Silver mylar tape
- Gold trim Monokote
- Both upper & lower surfaces
- Negligible mass added

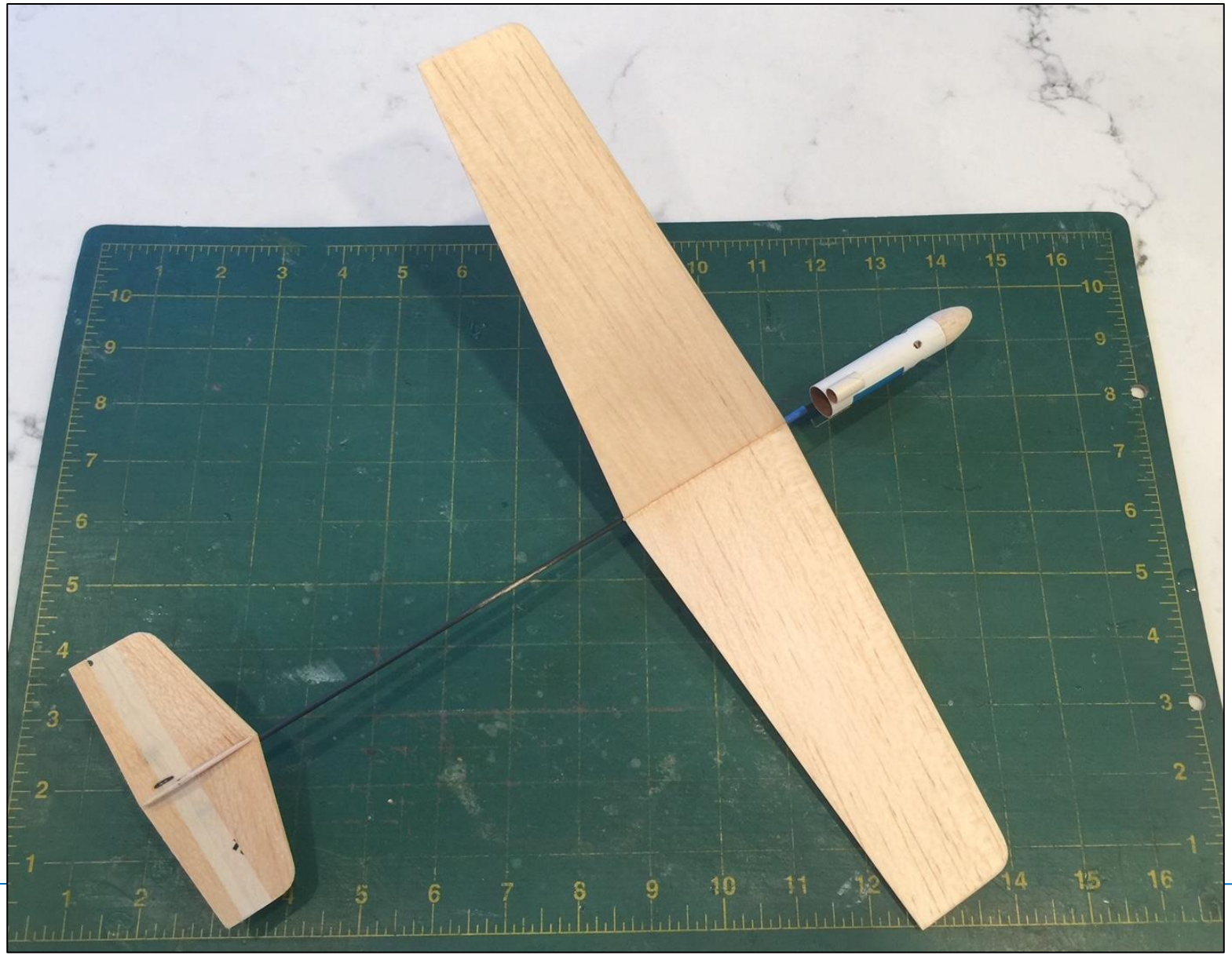
- Dethermalizers
  - Discussed later

DETAILS OF A SLIDE WING MODEL

Two Slide Wing Models



Slide Wing with Pop-Up Elevator

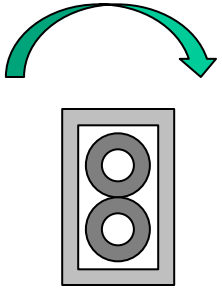


Slide Wing Design Features

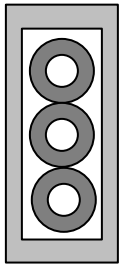
- **Wing**
  - Typically 1/8” balsa (5-6 PCF), maybe 3/32”
  - Wing span or aspect ratio can’t be too large, or wing will shred
    - Wingspan ~ 12”
  - Some aft sweep will help with flutter and divergence
  - Using 1/2A motors may allow higher aspect ratio
- **Horizontal and vertical stabilizers**
  - Typically 1/16” balsa (6-8 PCF)
- **Covering?**
  - Japanese tissue adds strength, but also adds mass
    - Good tissue getting harder to find
  - Dope or other paints add waterproofing, but also mass
  - Fly naked!

Slide Wing Design Features

- **Fuselage**
  - Stacked graphite tubes (0.078”)
    - 2, 3, or 4 tubes
    - More tubes add “roll” precision for wing position, but also mass
  - Lite ply or spruce for curved fuselages
    - Eliminates the need for pop-up elevator
  - 1/8” balsa with 1/64” plywood “T” slide
- **Wing slide box**
  - 3D-printed
  - Laser cut (Apogee Cirrus Breeze kit)
  - Traditional hand made (yes, it can be done!)
    - 1/64” plywood
    - Wrap with fiberglass or thread for strength

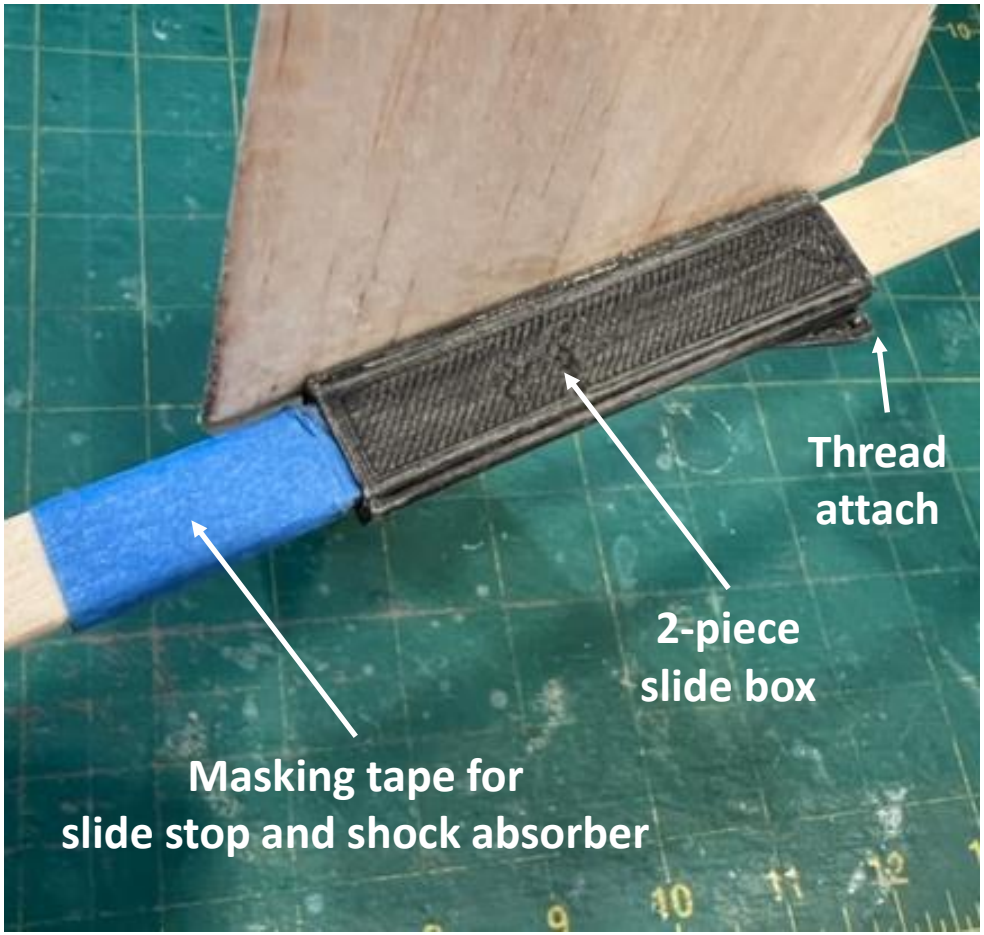


2 tubes



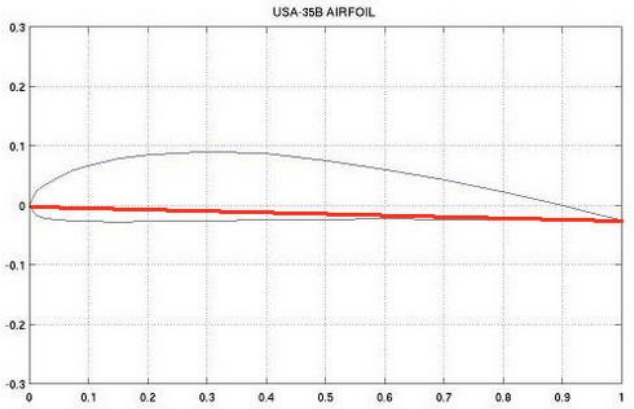
3 tubes

3D-Printed Parts for Slide Box and Thread(s)



Glide Transition of Slide Wing Models

- **Natural incidence from the wing airfoil**
  - 1-2°, depending on airfoil's zero lift line
  - Might work, depending on orientation of glider when wing slides forward…
  - … but significant probability that it won't transition to glide (i.e., death dive)



- **For multiround event, reliability is critical**
  - 100% glide transition is needed
- **Methods for additional incidence**
  - Pop-up elevator
    - Held down by string during boost, released at ejection
  - Curved fuselage
    - Wing at 0° incidence during boost, positive incidence for glide
    - 3° seems to give very reliable transition

SCISSORS/FLOP MODEL DETAILS

Model That Won the S4A Gold Medal (2021)

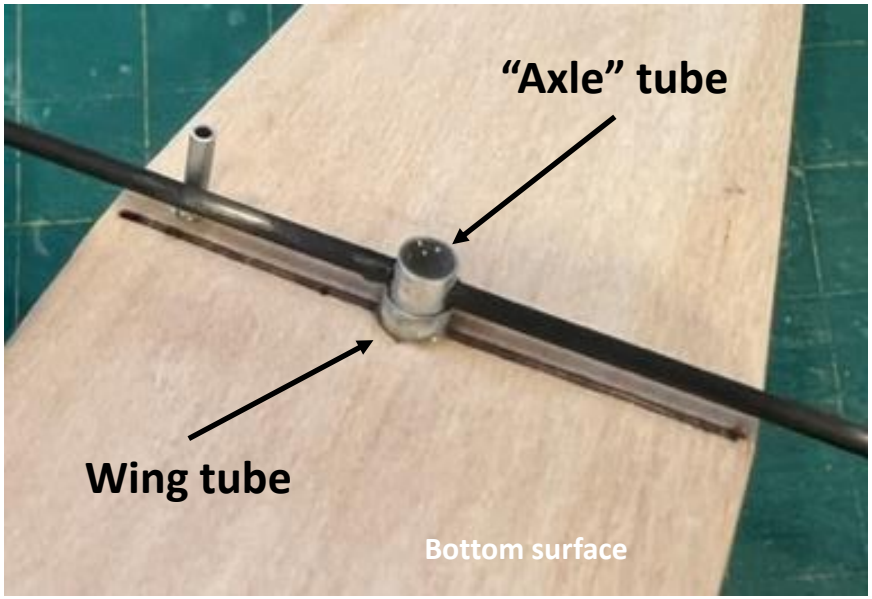
Scissors/Flop Design Features

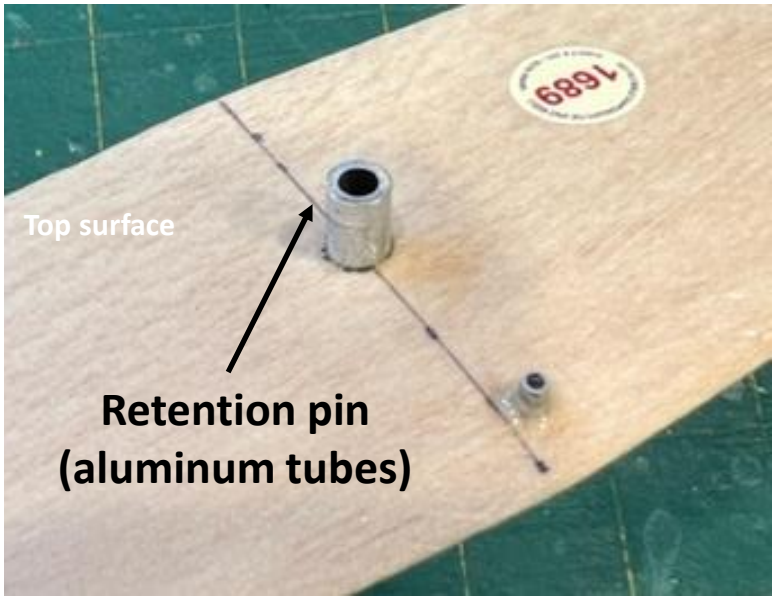
- **Wing**
  - Wing span or aspect ratio can be larger than slide wing
    - Wingspan ~ 18”
  - Typically 1/8” balsa (4-6 PCF), maybe 3/32”
  - Wing planform typically straight with tapered tips
    - Straight-taper is easier to airfoil
- **Horizontal and vertical stabilizers**
  - Typically 1/16” balsa (6-8 PCF)
- **Covering?**
  - Japanese tissue adds strength, but also adds mass
    - Good tissue getting harder to find
  - Dope or other paints add waterproofing, but also mass
  - Fly naked!

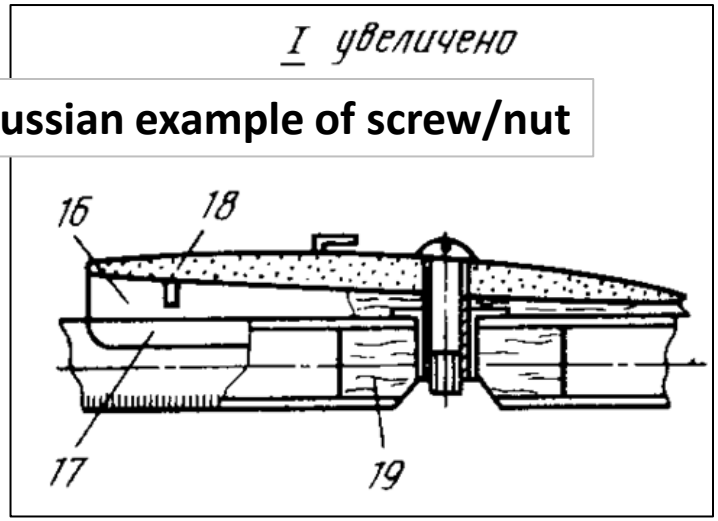
Scissors/Flop Design Features

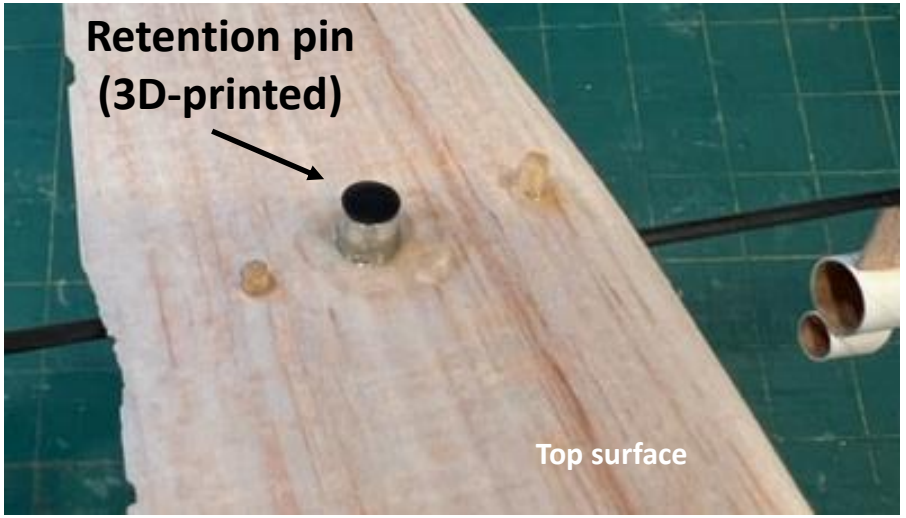
- **Fuselage**
  - Graphite tube, typically 0.098” diameter
    - 0.120” tube provides additional stiffness & strength with only small additional mass
    - Smaller tubes are too flexible
- **Wing pivot**
  - Metal screw and nut
    - Drill hole through graphite tube (difficult)
    - Cut tube, then splice tube with reinforcements
  - Aluminum tubes, nested
    - Central “axle” tube with hole for fuselage (7/32”)
    - Larger tube glued into wing (1/4”)
    - Nylon screw, 3D-printed pin, or aluminum tube to secure
  - Use assembly jigs for accurate assembly

Wing Pivot Features



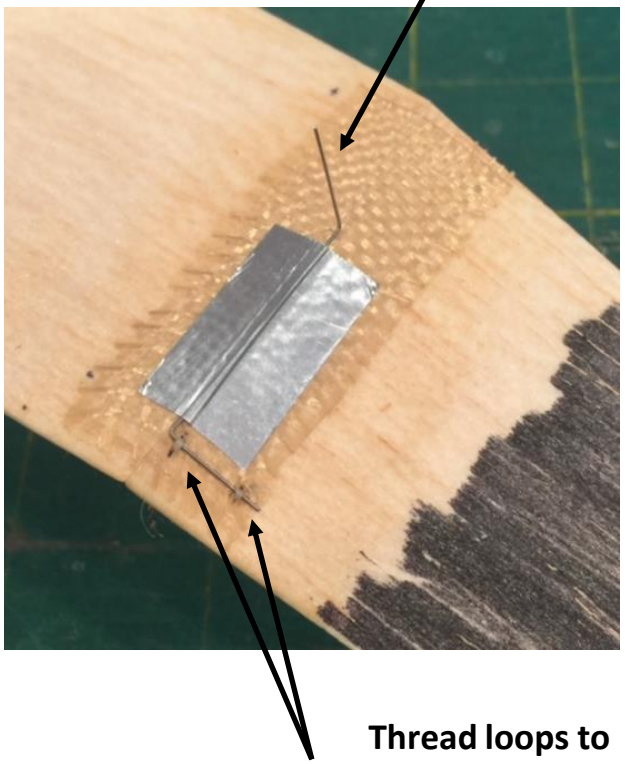






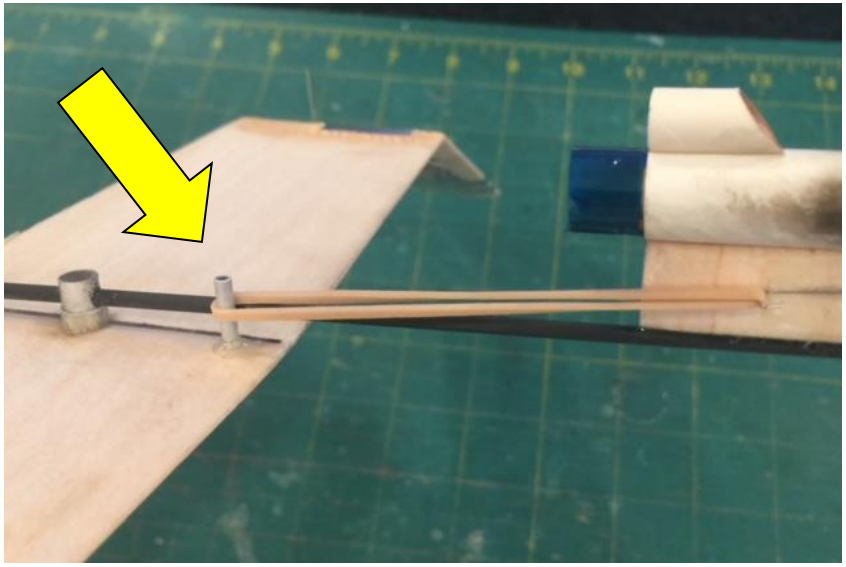
Flop Wing Hinges and Deployment

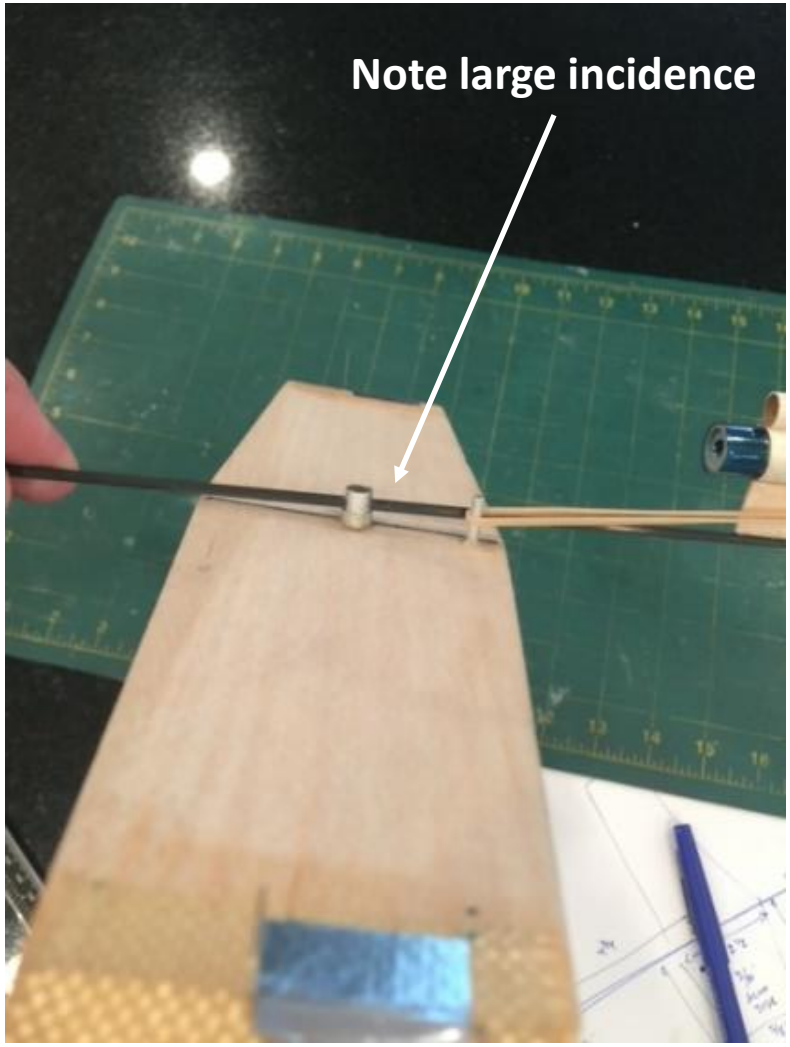
- **Hinges**
  - 1 oz Kevlar fabric* bonded to wing works well
    - Titebond works well
  - Tyvek tape
    - Aggressive adhesive
    - Will creep over time
- **Flop wing deployment**
  - Rubber bands aren't sufficient for 100% reliable deployment
  - Torque bars can work (Don Carson)
  - "Belt and suspenders" (Trip Barber)
    - Torque bars for initial ~90°
    - Rubber bands for remainder of deployment



[*] https://www.nar.org/fai-spacemodeling/construction-techniques/

Wing Scissors Rotation

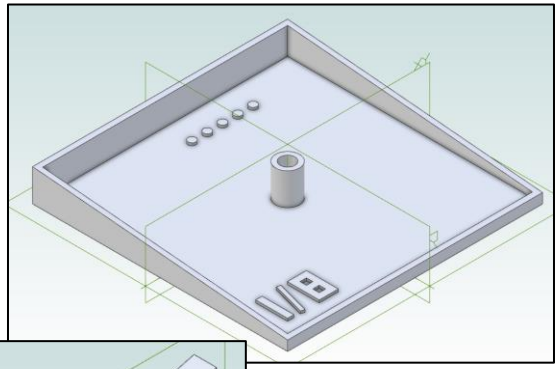


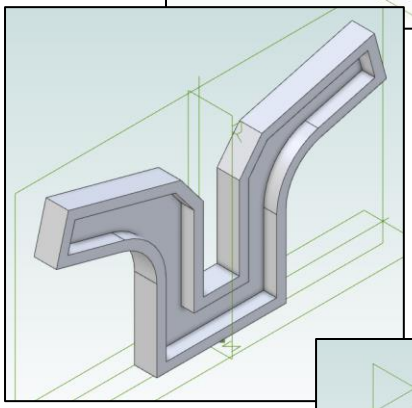


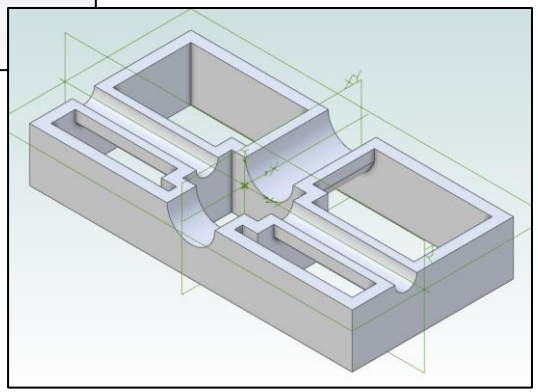
- Need a rubber band to rotate the wing
- Post can serve both the rubber band hook and the wing stop
- Euro designs often place the rubber band anchor far out on wing
  - Why?

Jigs for Accurate Assembly

- Wing tube to wing at specified incidence angle
- Axle tube to fuselage (perpendicular)
- Wing-to-wing box
- Motor pylon and motor tube
- 3D-printed or manual



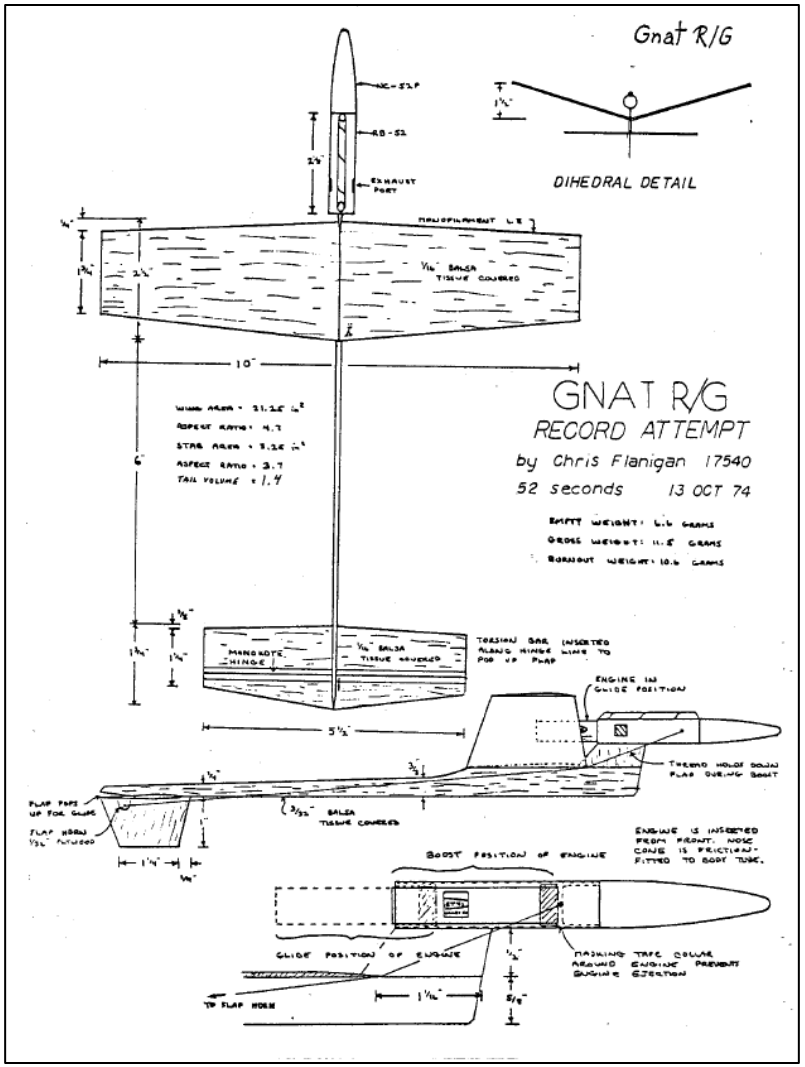


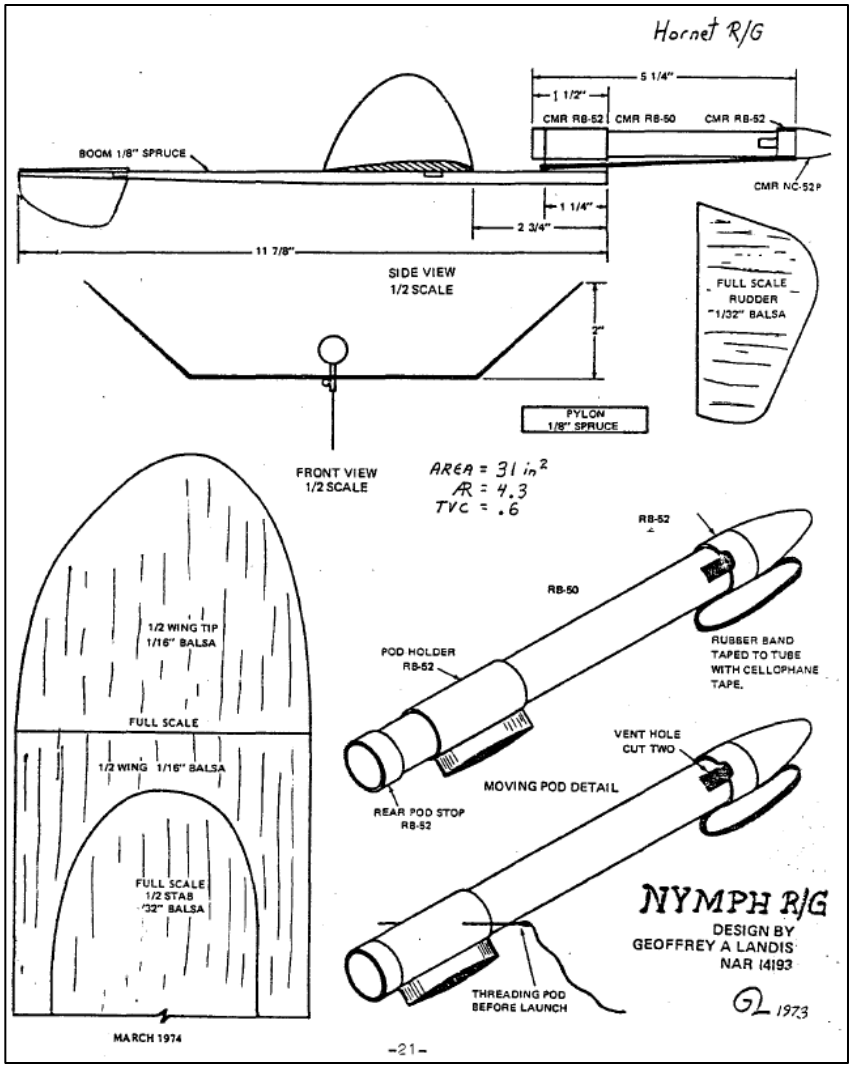


Vintage Designs

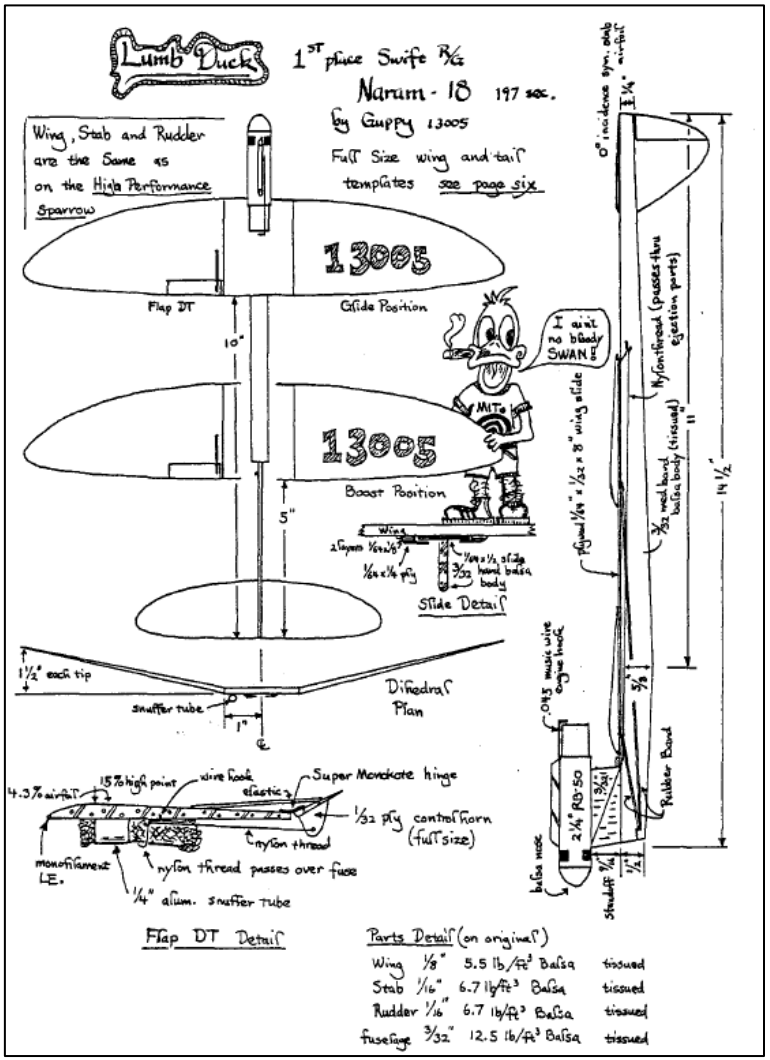
FLASHBACK

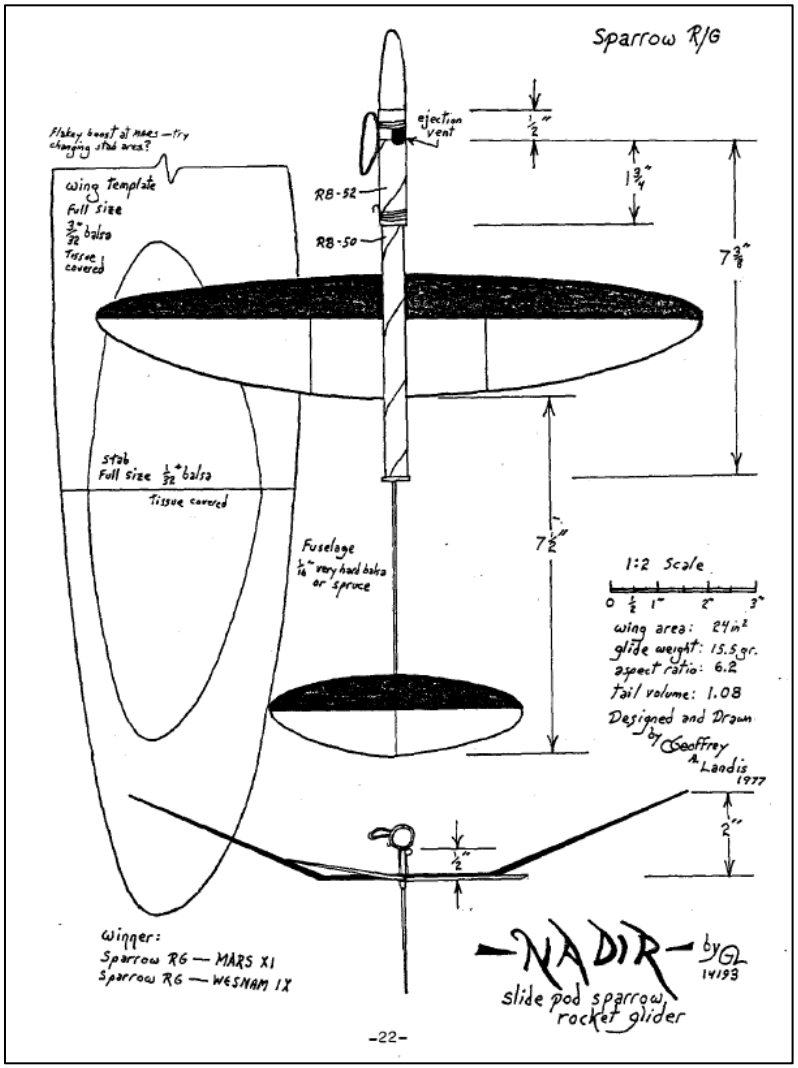
MIT Competition Design Notebook





MIT Competition Design Notebook





S4 MODELS

https://www.nar.org/fai-spacemodeling/fai-events-for-wsmc/s4-boost-glider/

Venus “Gizzard” R/G (OOP)

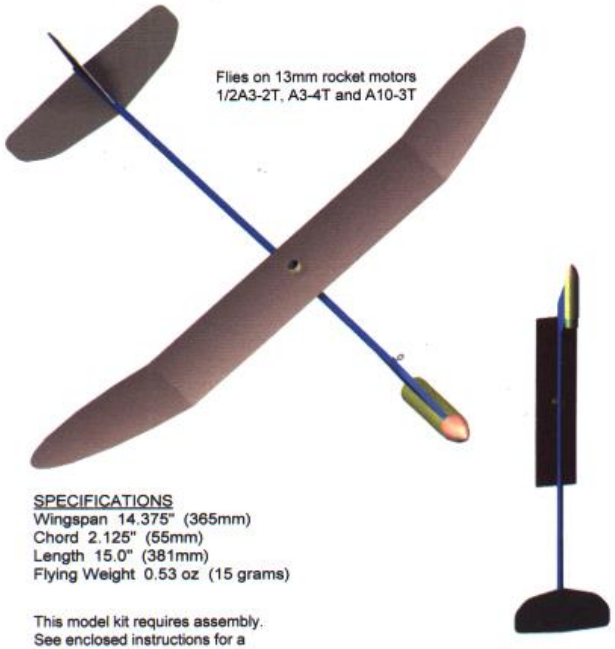
Venus Model Rocketry

EXPLORING NEW HORIZONS IN MODEL ROCKET DESIGN

GIZZARD

Scissor-Flop Winged Rocket Glider

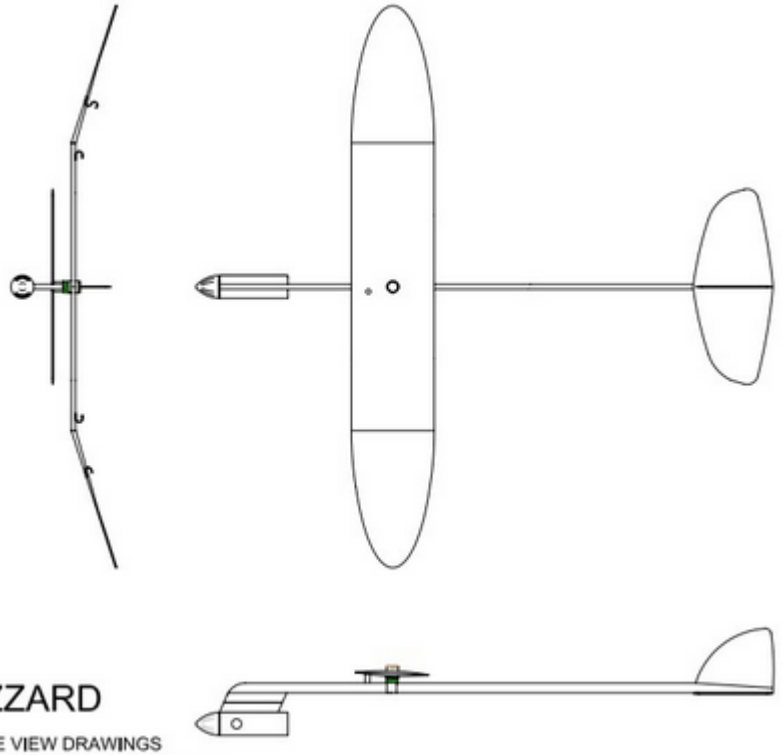
Almost Ready to Fly



SPECIFICATIONS
Wingspan 14.375" (365mm)
Chord 2.125" (55mm)
Length 15.0" (381mm)
Flying Weight 0.53 oz (15 grams)

This model kit requires assembly. See enclosed instructions for a list of items needed to complete the assembly.

Rocket motors and launch equipment not included.



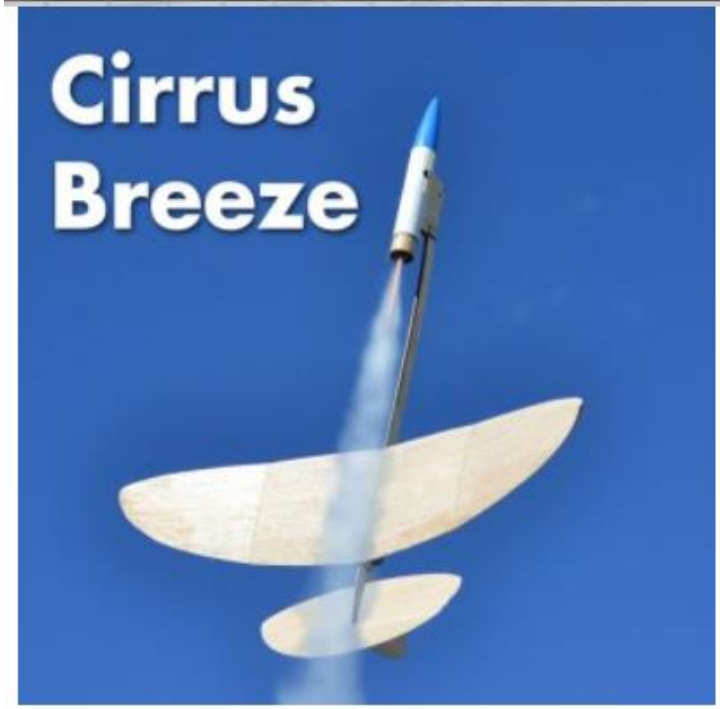
GIZZARD

THREE VIEW DRAWINGS
(DO NOT BUILD FROM DETAILS)
SCALE: 3/8"=1"
12.20.05

http://ashasta-sadie.com/2020/10/16/gizzard/

Apogee “Cirrus Breeze” Kit

CIRRUS BREEZE ROCKET GLIDER



- **Model**: 05023
- **Skill Level 5**: Extremely Challenging
- **Length**: 13.000" (33.02 cm)
- **Fin Span**: 11.880" (30.18 cm)
- **Fin Count**: 3
- **Motor Size**: 13mm
- **Recovery System**: Glider
- **Launch Pad Type**: Low Power
- **Manufactured by**: Apogee

Additional Info:

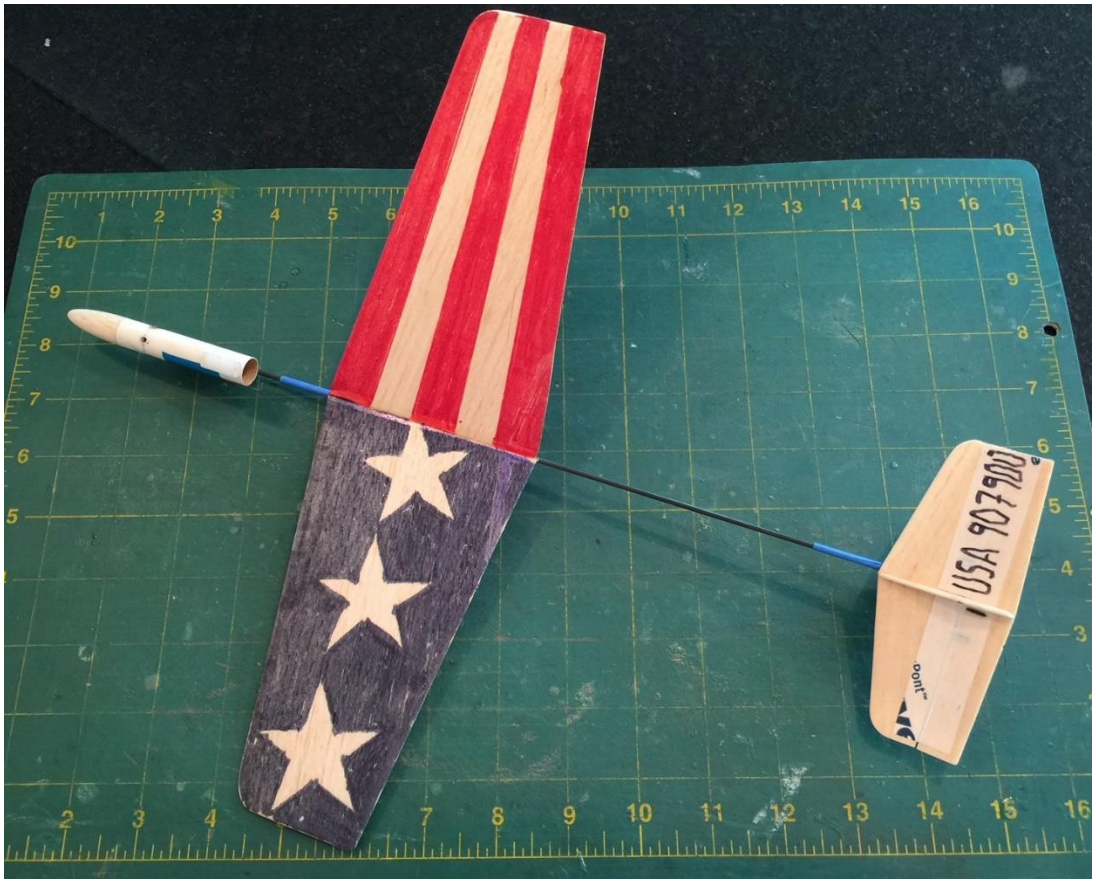
- Unique curved fuselage for no-hassle trimming
- Laser-cut balsa wood construction
- Assembly jigs included for extra precision.
- Made in USA!

$24.53

Product is

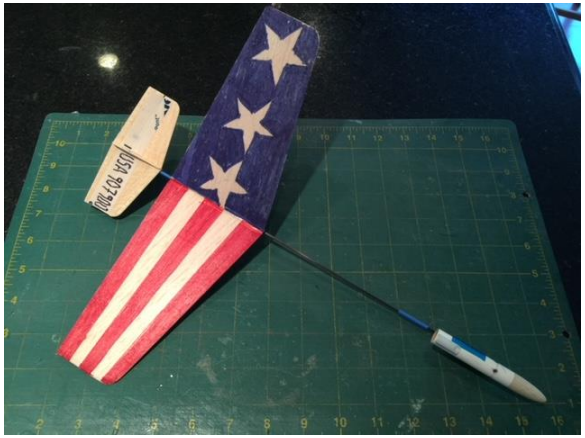
If insufficient or out of stock, c

Slide Wing by Chris Flanigan



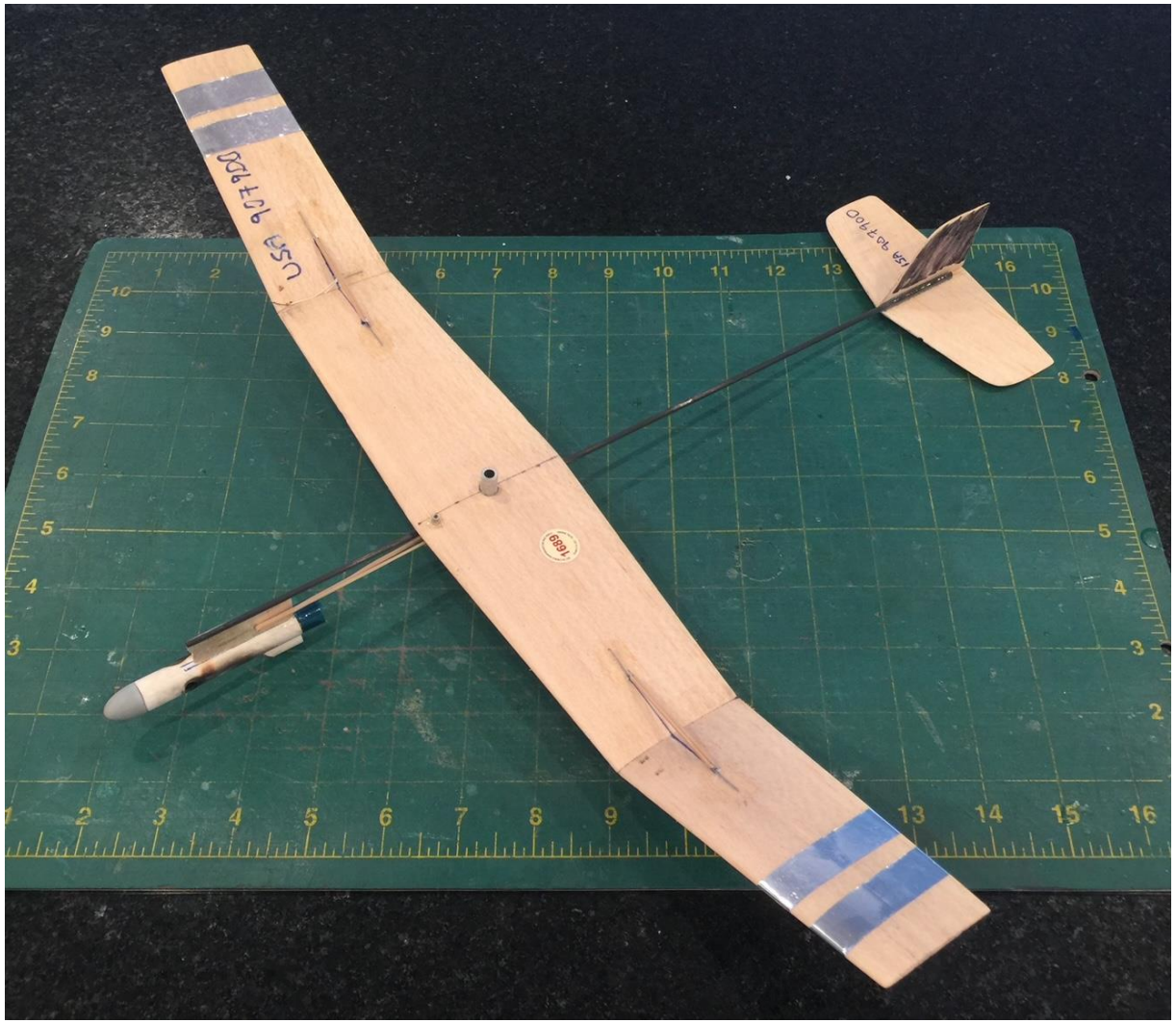
Glide configuration

Boost configuration

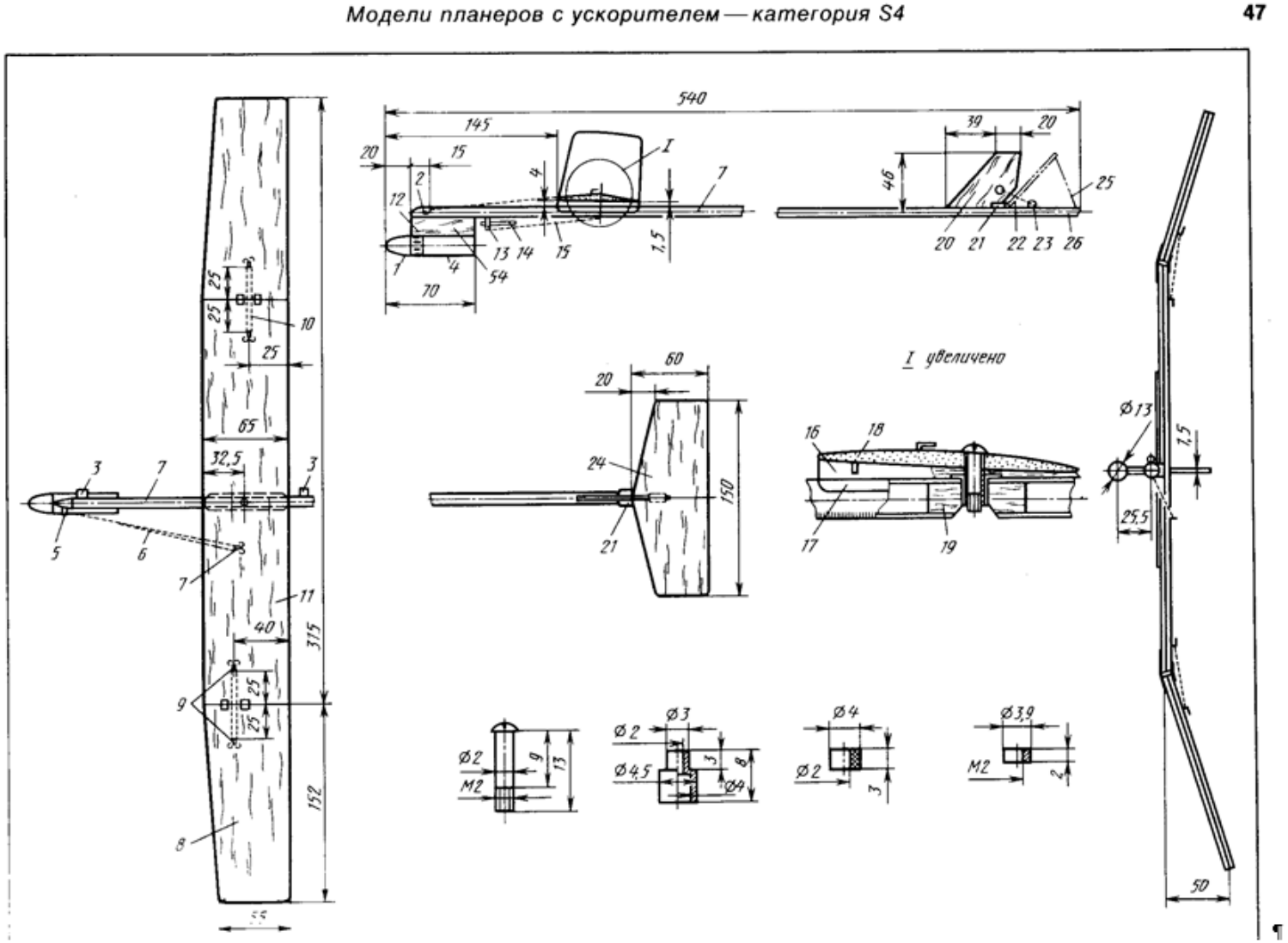


6th place at 2019 ESMC

S4A Design by Chris Flanigan



Russian S4A Design



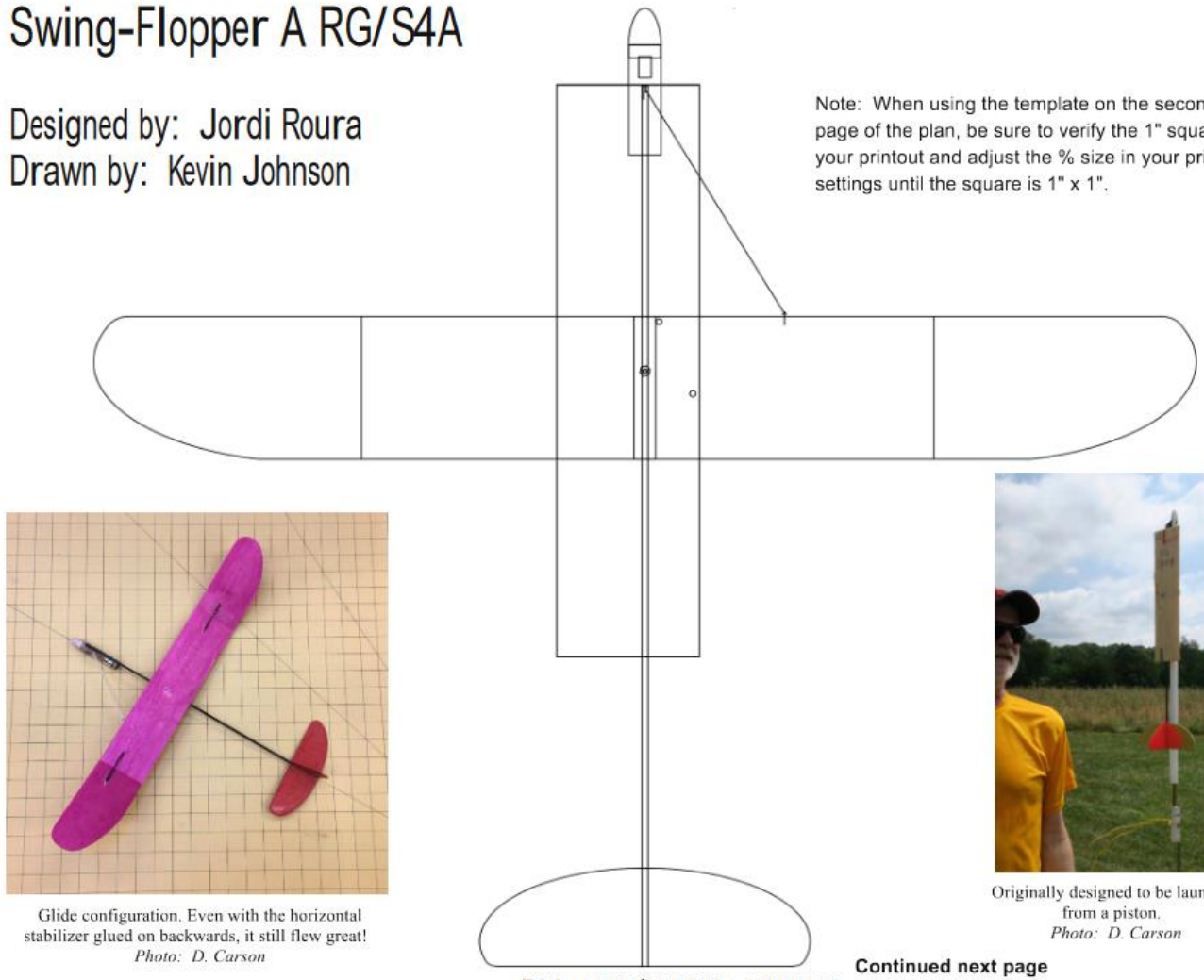
https://www.nar.org/wp-content/uploads/2014/05/Russian-FAI-Flop-Pivot-S4A.doc

Spanish S4A Design

Swing-Flopper A RG/S4A

Designed by: Jordi Roura
Drawn by: Kevin Johnson

Note: When using the template on the second page of the plan, be sure to verify the 1" square on your printout and adjust the % size in your print settings until the square is 1" x 1".



Glide configuration. Even with the horizontal stabilizer glued on backwards, it still flew great!
Photo: D. Carson

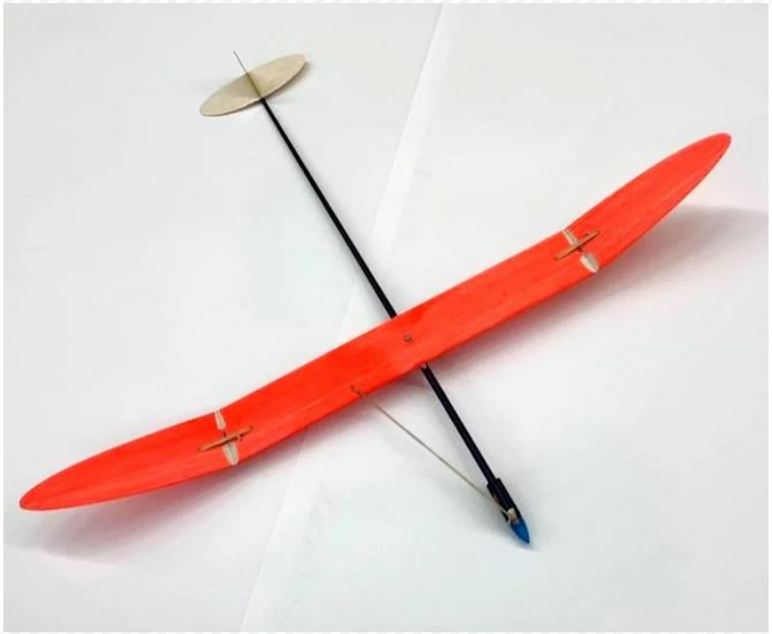
Originally designed to be launched from a piston.
Photo: D. Carson

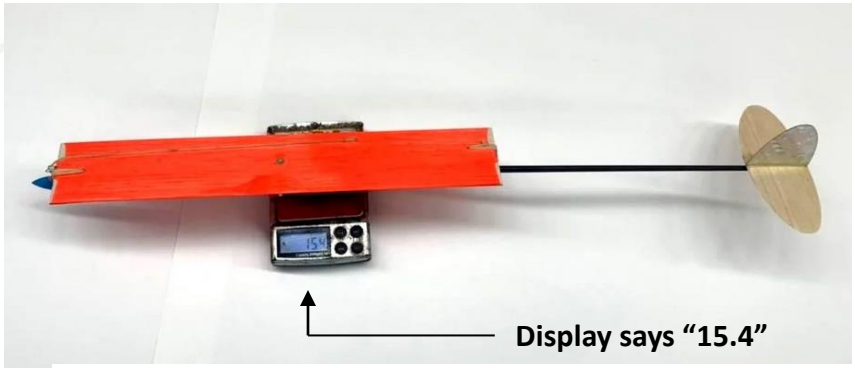
Continued next page

https://www.nar.org/wp-content/uploads/2018/12/Spanish-S4A-Design-2018-1.pdf

S4A Models from Poland

Russia (Rocket Craft Master)





Boost/glide duration model S4A

Boost/glide duration model S4A for FAI competition.

€70.00

Диаметр двигательного отсека

https://en.rocketcraftmaster.com/product-page/boost-glide-duration-model-s4a

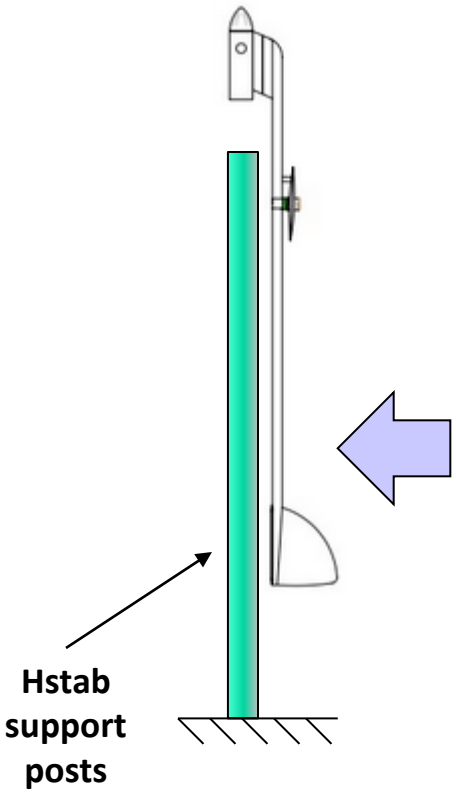
Observations from Local and Intl Contests

- Scissors/flop is very dominant design for S4
  - Occasionally, a unique design or two (slide wing, adjustable flaps)
- Among scissors/flop designs, much similarity with a few variations
  - Sizing
  - Wing aspect ratio
- Some use of composite materials
  - Russian commercial models (Rocket Craft Master)
  - Vacuum bag composite/foam wings (Vinyard, Kuzek, UK)
- Some use of 3D printing
  - Wing slide boxes, thread guides, dihedral stops
  - Assembly jigs

ANCILLARY ISSUES

Additional Issues for S4

- **Launching – in windy conditions**
  - Launch rod – 3/16” for rigidity
  - Piston, or piston with rail
  - Need to support tail in windy conditions
- **Dethermalizers**
  - Fuse, silly putty, electronic, RC, trackers
  - Problems: mass, reliability, “TRL”
- **Boost altitude**
  - Pistons can help increase altitude
  - Pistons can help shred a model (uh-oh)
  - Slide wing models can boost higher than scissors/flop
- **Reliability – use a checklist!**



Additional Issues for S4

- **Improved performance**
  - Glide performance is related to mass and $C_L^{1.5}/C_D$
    - Lighter is better (up to a point)
    - Better airfoils for low Rn (difficult)
  - Don't forget about the C_D part!
    - Higher AR wing, aerodynamically "clean" (torque bars)
- **Thermals – reading "air"**
  - Technology, practice
- **Fly a lot**
  - "Americans build, Europeans fly"
  - Better designs & materials can help – but not if they don't work
    - OTOH, you probably won't win flying a "brick"
  - 100% reliability

Words of Wisdom

Be a good sportsman, though; it does pay. Love thy fellow competitor ..... most of them are pretty good guys. Model rocketry is fun!

Geoffrey A. Landis
Editor

Q&A