Design of a Competitive Heliroc

Research and Development Report, NARAM44

By CHEDAR_1++ Team

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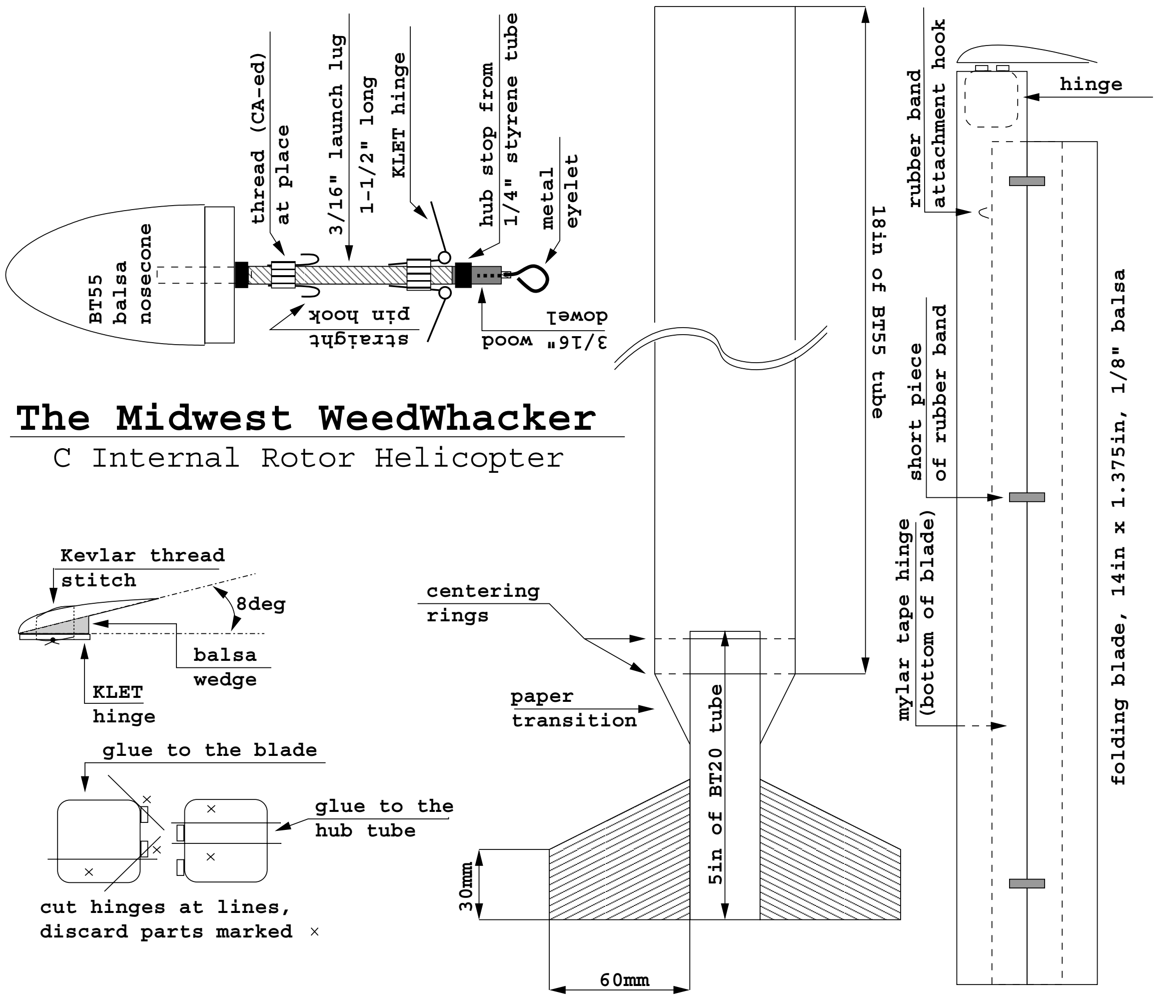


OUTLINE

- **Motivation & Goals**
- **Reliability issues**
- **Improving the reliability**
- **Improving performance**
- **Altitude performance comparison**
- **Results discussion**
- **Conclusions**

MOTIVATION & GOALS

- **MOTIVATION**
  - The DQ rate at helicopter duration events is high
  - The same old designs keep dominating the field of entries despite of number of problems they suffer from
  - The solutions to those problems exist but are not generally known or implemented
- **GOALS**
  - Research and design competitive heliroc of reasonable complexity

    Competitive = Reliable + Well Performing
  - Make the design scalable and versatile
  - Make the design available to other competitors to inspire further developments

RELIABILITY ISSUES

Burn string release failure: burn string often cuts into a blade or fails to burn. The result is a non-deployment of the blades.

Ejection after apogee: the aerodynamic forces acting on the rocket streamlining to the ground keep the blades by the body. Again, the result is a rotor nondeployment.

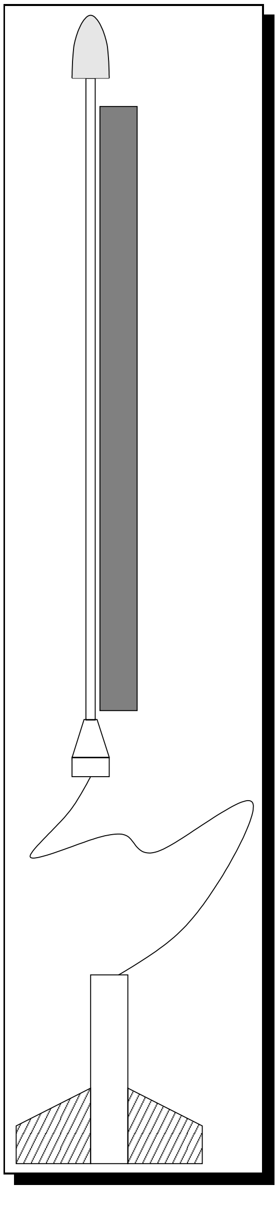
Flip on the descend: heliroc can flip upside down, rotor keeps rotating but is in an ineffective mode (faster drop time)

Poor stability on boost: helirocs need large fins to compensate for the drag added by exposed rotor blades.

Shred on boost: blades are exposed to extreme stress (especially at high impulse classes).

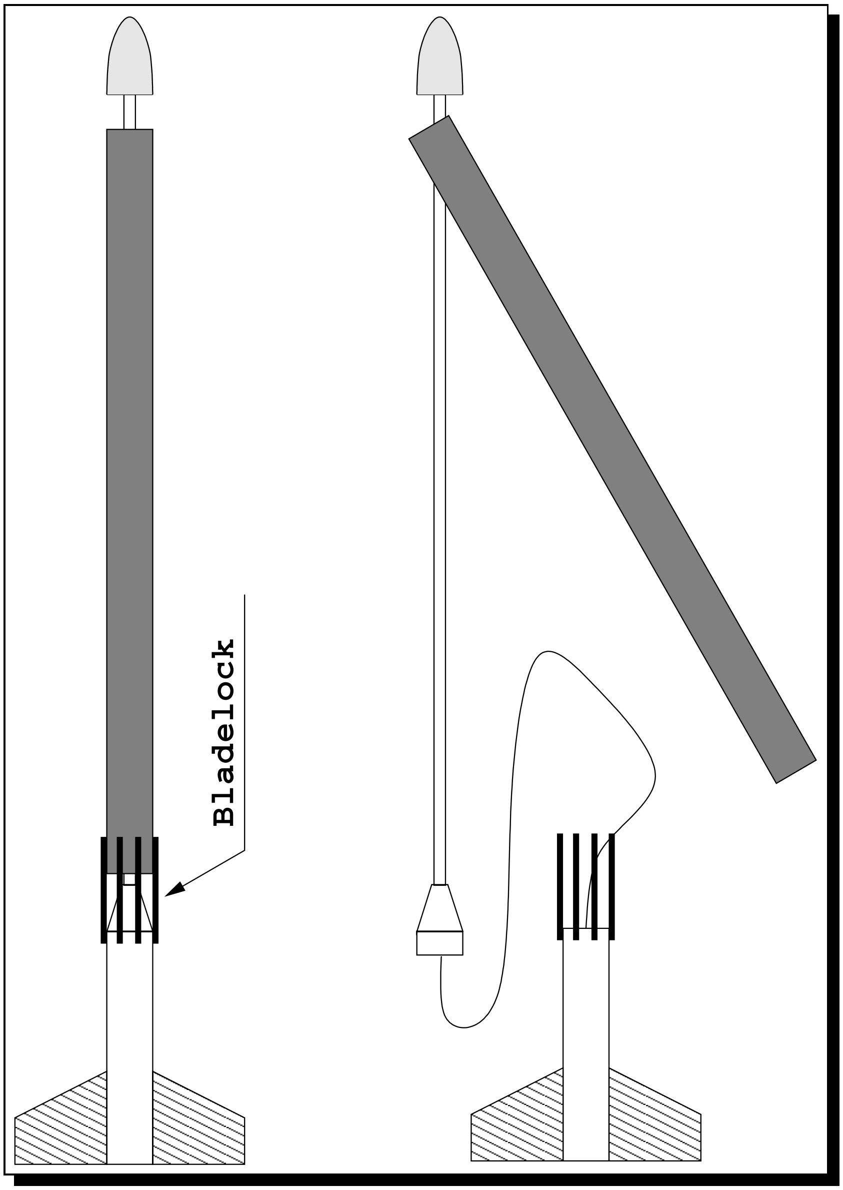
IMPROVING THE RELIABILITY

Booster-rotor separation: destroys the aerodynamic stability at the ejection. This solves the problem of post-apogee ejection, the heliroc starts tumbling and the rotor eventually deploys. Booster-rotor separation also prevents rotor flipping.



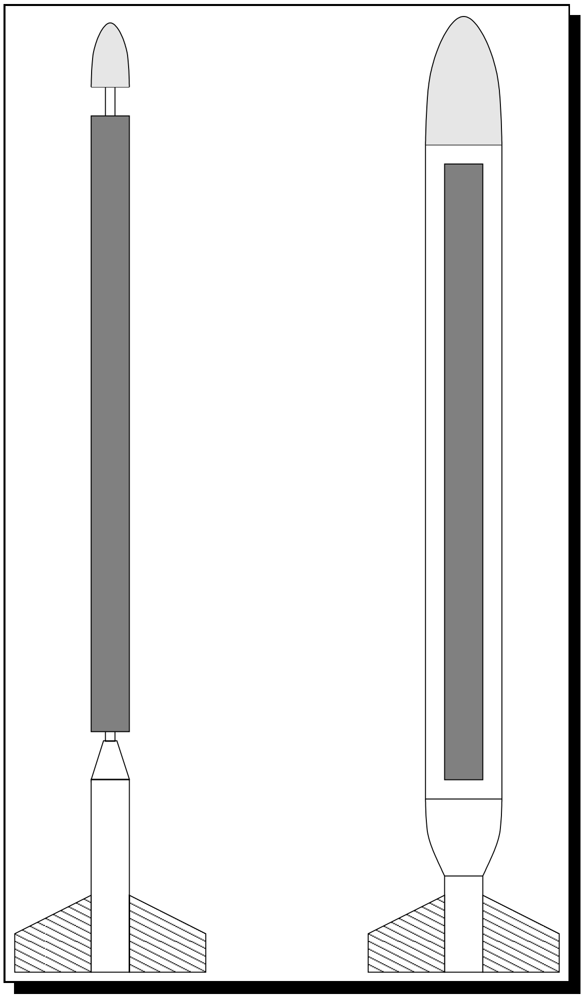
IMPROVING THE RELIABILITY

Blade tabs: replace the burn string. Used on booster-rotor separating models, the blade tabs provide reliable blade release. Other similar solutions are possible



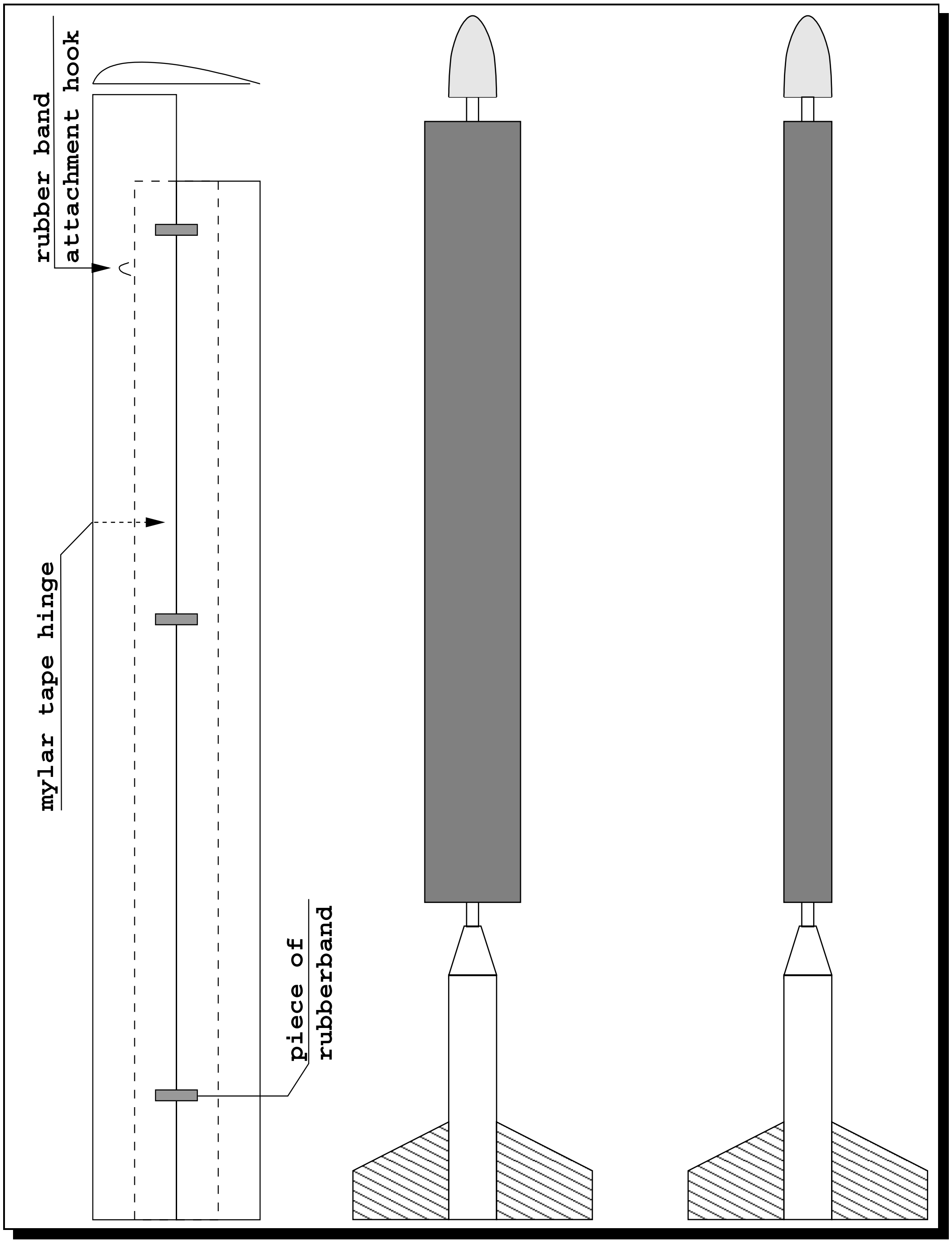
IMPROVING THE RELIABILITY

Internal rotor heliroc: blades are carried inside the body tube and protected from the stress on boost. Internal rotor helirocs also have low drag coefficients which improves their boost performance. However, the price to pay is bigger frontal area and possibly increased weight.



IMPROVING THE BOOST

Folding blades: the blades fold lengthwise in half, thus packing more tightly around the body.



FOLDING BLADES PERFORMANCE

Do folding blades have lesser performance?

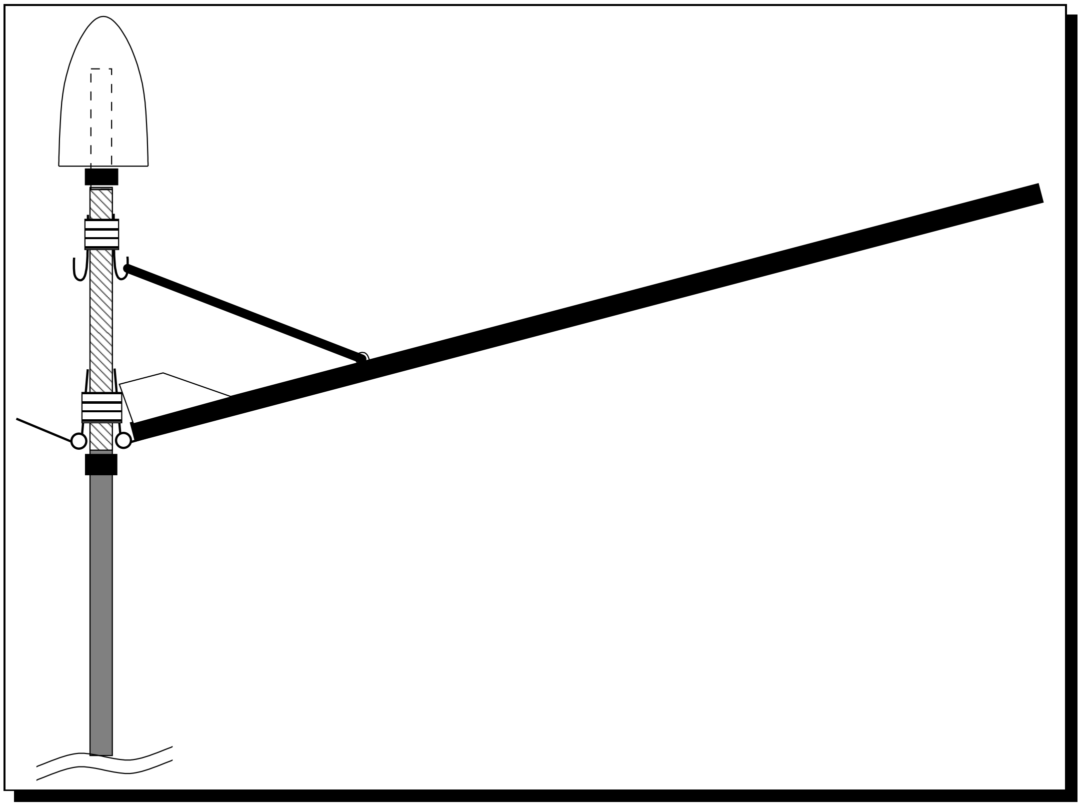
Adding the mechanism to folding blades adds weight and drag. To find out whether this change is significant, the drop test from 45ft watchtower were conducted.

Drop #	folding blades	plain blades
1	5.90s	4.98s
2	5.31s	5.44s
3	5.10s	5.93s
4	5.59s	5.87s
5	5.54s	5.71s
Avg	5.49s	5.59s

There is no significant performance decrease caused by adding additional elements to folding blades.

IMPROVING THE ROTATION

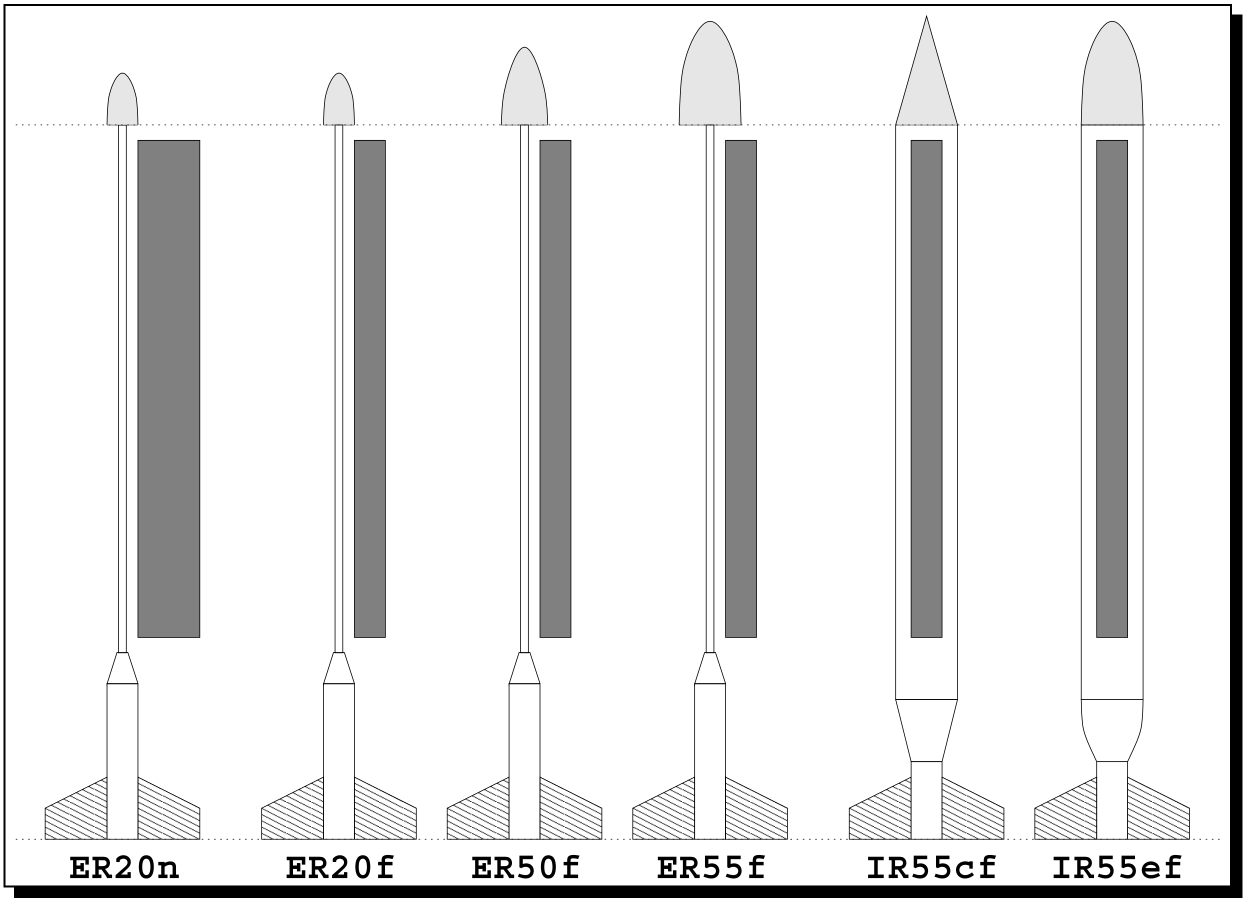
Freewheeling hub: Only the rotor spins, not the whole model. Thus more energy is converted into autorotation.



Variable pitch blades: twisted blades have negative angle of attack at the hub (this part induces autorotation) and zero or slightly positive angle of attack at the tips (this parts creates lift).

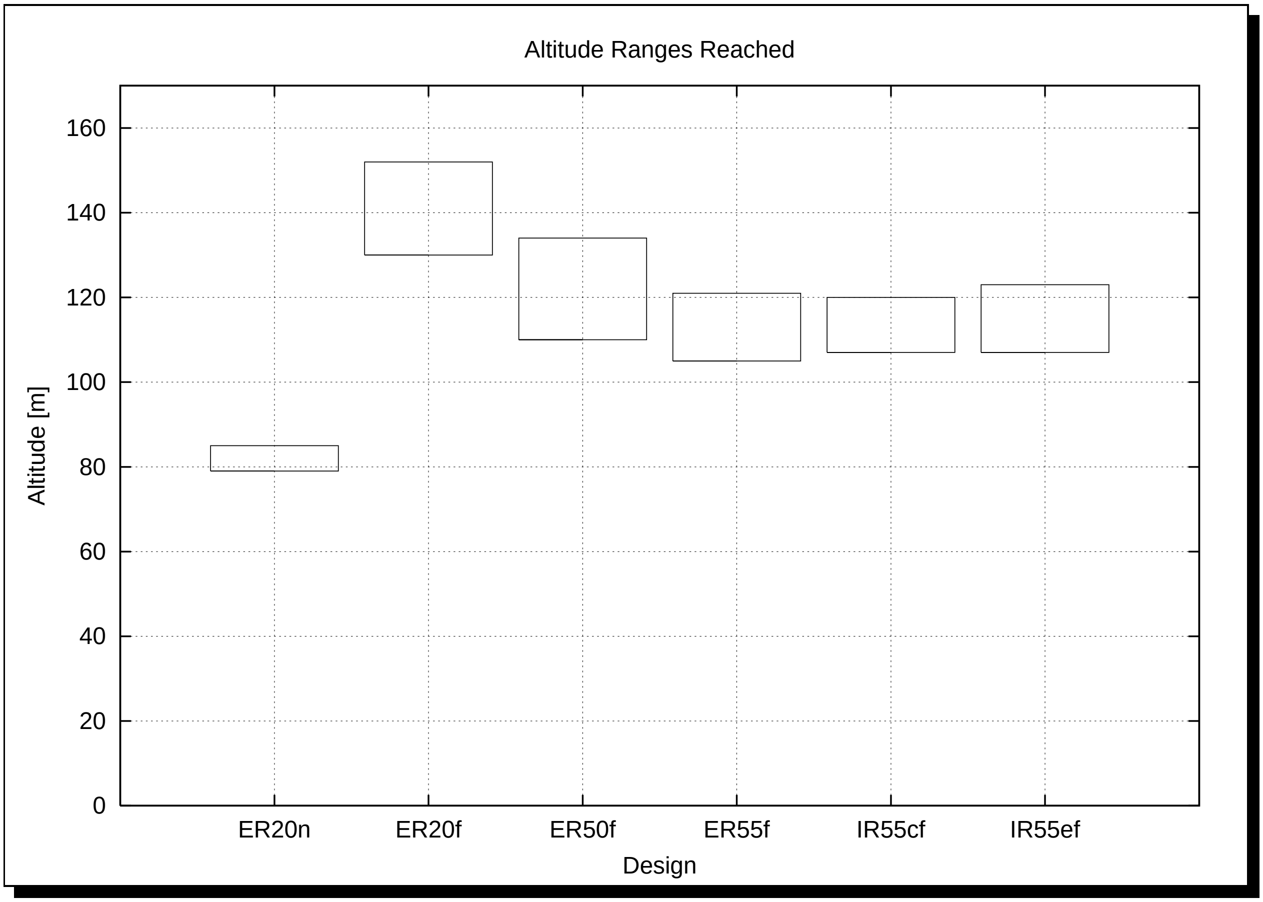
MODELS COMPARED

Compared models: Six models derived from the same design were compared. All models were as similar as possible, differing in only few design elements.



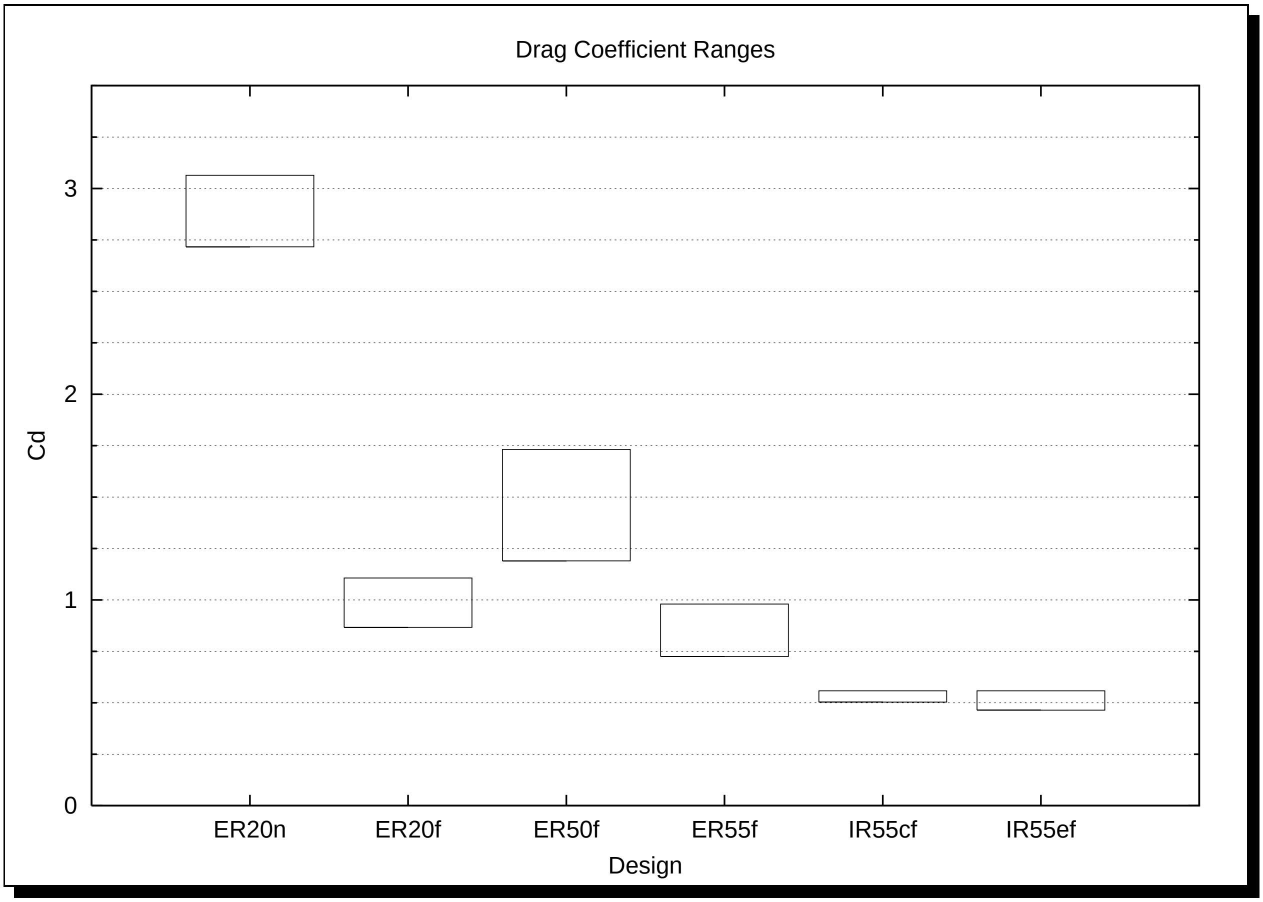
MEASURED ALTITUDE

Altitude: Altitude ranges achieved by the models are shown on the graph. The altitude was measured using standard two station tracking with 300m long baseline



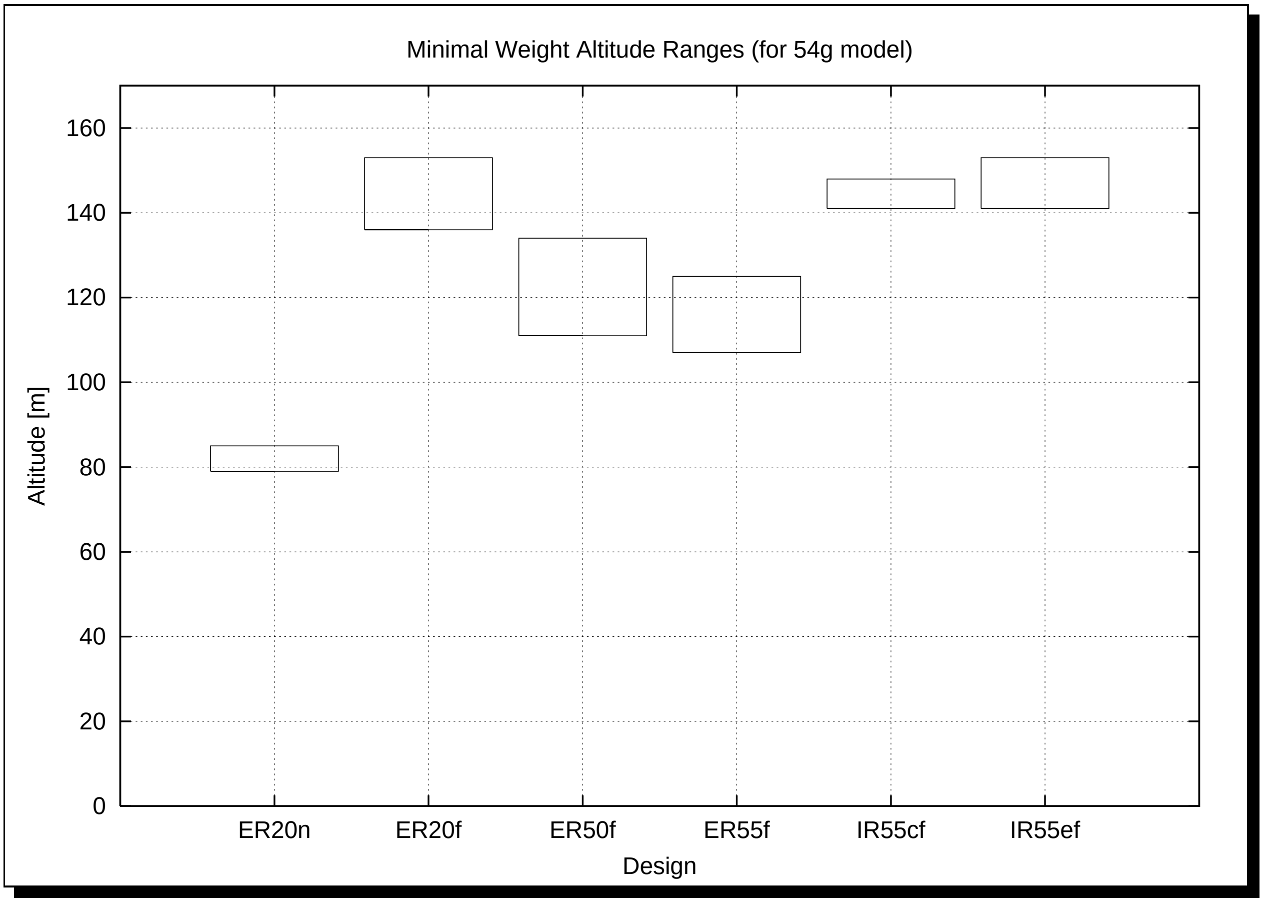
DRAG COEFFICIENTS

Drag coefficients: Drag coefficients were computed from measured altitudes and model parameters using the software application wRASP.



MINIMUM WEIGHT ALTITUDE

Minimum weight altitude: To further compare the performance of the models, the minimum weight altitude was computed using drag coefficients (obtained in previous simulations) and known model parameters. The minimum weight altitude is the altitude that the model would achieve, should it have the mass of the lightest model from the set.



WEIGHT REDUCTION ON IR MODELS

Weight reduction: Internal rotor helirocs built for this project are heavier than necessary. Following weight reductions are possible :

Use vellum tube	-12g
Replace balsa shoulder with vellum	-3g
Replace balsa nose with VacuForm	-4g
Use smaller fins	-1g
Total savings	20g

Because of the questionable robustness of the lightweight model, we have built and launched it. The model boosted fine, unfortunatelly no altitude tracking was available. The lightweight model is being developed further for the use in competition.

CONCLUSIONS

- Reliability problems of helirocs were researched and the solution were suggested and implemented. The qualification rate was 94%.
- Reliable and scalable models (with both internal and external rotor) were developed and tested.
- Selfcontained minihub was developed. This minihub can host blades of different sizes and designs (including twisted blades).
- Folding the blades increases the boost performance by large amount at almost no cost.
- Internal rotor helirocs have the smallest drag coefficient from all models tested, but the attention needs to be paid to their overall weight. Additionaly, they provide protection of blades on boost and are a good choice for high impulse classes.
- Internal rotor heliroc plan (US record setter) published to encourage the use and development of internal rotor helicopter designs.