VARIOMETER

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THE UPS AND DOWNS

OF THE

KANSAS SOARING ASSOCIATION

Editor: Tony Condon

Volume LVIII **September 2018** **Number 8**

Perlan II Sailplane at ~76,000 Feet!

KSA Calendar

2018

September 6th-10th - Aces High Aerobatic Contest - Newton

September 8th - KSA Meeting - Cookout at Sunflower

September 20th - 23rd - Great Plains Vintage Rally - Wichita Gliderport

September 27th - 29th - Kansas Air Tour

October 6th - EAA Fly In - Jabara

October 13th - KSA Meeting - Elections

October 20th - 21st - Soaring Safari to Atwood

November 3rd - Fall Work Day at Sunflower

November 10th - KSA Meeting

November 10th - Fall Work Day rain date

December 8th - KSA Meeting

2019

January 12th - KSA Banquet

February 9th - KSA Meeting

February 9th - NWS Aviation Weather Symposium - Wichita

March 9th - KSA Meeting

June 2nd - 13th - Club Class Nationals - Sunflower

July 20th - Kansas Kowbell Klassic

Runway Heaves

On your next trip to Sunflower you may notice that the yellow markings on the runway are gone. This is because SSF arranged for the heaves in the pavement that they were marking have been removed. They were ground out and replaced with fresh asphalt. The entire width of the runway is now completely useable for takeoff and landing. Enjoy!

LS-4A For Sale

1400 hrs
Good cobra trailer.
Has been landed gear up in 2008. Repaired professionally..
Some yellowing of the gelcoat. Good solid glider.

25k

Gary Guinn
g.guinn@maccor.com
918 704 0277
Tulsa, OK

Sunflower Seeds

August 1st - **Bob Holliday** towed **Jerry Boone** (K7) and then self launched in RZ. **Jerry** made 200km to the northeast with a landout northeast of Hutchinson. **Bob** flew in the same direction but made it back after struggling low on the final leg. **Mike Orindgreff** (F8)

August 2nd - **Mike Orindgreff** (F8) had a short local flight

August 6th - **Mike Orindgreff** (F8) had another short local flight

August 7th - **Tony Condon** towed in the evening for **Wilder Parks** to get a few flights in the 1-26. Jacob Frye and Jessica Brooks helped run wings.

August 9th - **Mike Orindgreff** (F8) had a couple hour soaring flight

August 10th - **Mike Orindgreff** (F8) made 275 km, running NE/SW lines at about 5000 ft.

August 11th - **Bob Hinson** towed. **Paul Sodamann** ran wings. **Tony Condon** (K), **Keith Smith** (LW), **Dave Wilkus** (SR), **Dave Pauly** (Pipistrel), and **Mike Orindgreff** (F8) all went soaring. **Steve Seibel** and **John Peters** made flights in the 1-26. **Matt Reese** flew the 2-33. Lift was slow to start at Sunflower. **Tony** got away early and made his first turnpoint at Ashland before abandoning task at Freedom, OK, overflying Cherokee, OK, and landing at Kingman. **Paul Sodamann** aerotowed him back.

August 12th - **Brian Bird** towed. **Ray Girardo** ran the line. **Tony Condon** instructed in the 2-33. Day started out with a few guest rides. Students included **Robert Estagin**, **Rob Rippy**, **Josh Maes**, **Steve Damon**, and **Mike Davis**. Soaring conditions cycled with rain showers in the area in between. Early flights enjoyed run along developing street over Sunflower. Late flights had nice thermals. **Paul Sodamann** (BB) and **Bob Hinson** (KD) flew. **David Kennedy** observed. **Michael Groszek** had a nice late soaring flight in the 1-26. **Mike Orindgreff** (F8) flew to Hays and back, but needed the motor 3 miles out from Sunflower! Rats!

August 17th - **Mike Orindgreff** (F8) flew 130km

August 18th - **Paul Sodamann** towed. **Tony Condon** (K), **Keith Smith** (LW), and **Mike Orindgreff** (F8) went soaring. **J Riedl** did some solo flights in the 2-33. I think **Mike Davis** did too. **Tony** went to El Dorado and Hillsboro before landing out at Moundridge. **Mike Logback** provided the aerotow retrieve this time.

August 21st - **Mike Orindgreff** (F8) made 120 km flight

August 24th - **Mike Orindgreff** (F8) flew the WSA triangle

Member Accomplishments

Kirk Bittner passed his Commercial Airplane Checkride. Glider next!

KSA Contest Results

Jerry Boone placed 4th at Region 10 South in Houston, flying his Zuni. Very nice!

Steve Leonard flew his Nimbus 3 to 9th in the Open Class Nationals in Uvalde

Bob Holliday placed 12th in the Open Class Nationals in Uvalde, flying his ASH-31mi

Notes from the President

Greetings KSA! We are headed towards fall with a full head of steam and lots to look forward to. Coming up soon is the annual Vintage Rally at the Wichita Gliderport. October will be action packed with the EAA Fly In, KSA Meeting, and an Atwood outing on the schedule. The Fall work day at Sunflower will be the first weekend of November.

Gary Worthy at Atwood has invited all of us to bring our gliders out to Atwood the October 20th weekend. The Cessna AgWagon that **Brian Bird** equipped for towing will be doing the pulling. They would really love it if we could get a two seater out there to give some rides. If you're interested, let **Brian** or I know at abcondon@gmail.com or BirdB@hutchcc.edu.

KSA elections are held in October, and this year the bulk of the board positions are up. President, both Vice Presidents, Towplane Manager, and two Director positions are open. If you are interested in serving the club please contact me, abcondon@gmail.com or 515-291-0089. Ballots will be in next months *Variometer* and voting will take place at the October meeting.

Progress on the Grob continues and I am still expecting that we will be flying it in October. We've had a great turnout of help whenever it's been requested. Thanks to everyone who's pitched in so far and those who will be helping in the next few weeks!

I know a few members are planning to go to Denver for the ground school being held in October. I suggest you coordinate car pooling on the Soar-Kansas group.

BIG NEWS - SSA has approved the bid and the 2019 Club Class Nationals will be held at Sunflower! This is incredibly exciting. The last National Championship that was held at Sunflower was in 1989! Expect the contest to be a regular discussion item at the meetings this fall and winter. SSF will be working on improvements to the airport to help us host this event. 12 Pilots are already signed up to compete. This will require a strong volunteer effort from all of us, but with the experience we have from hosting Regionals in 2013, 2014, and 2018 I know we are up to the task.

Meeting places and topics are needed for this winter. We typically meet the second Saturday of the month. I expect October meeting to be at Sunflower since we will still be flying. November - April we will seek an indoor venue. Speakers and subjects are needed. Have an idea or have something to offer?

On February 9th the National Weather Service in Wichita is planning to host another Aviation Weather Seminar. The last one was excellent. They have requested that we provide a speaker to discuss a soaring related item. Mark it on your calendars!

There is still a lot of season left and many opportunities for continuing to reach for soaring achievements or training milestones. I'll see you at Sunflower!

Tony

The Glider Pilots Ground School is back on the road to Denver, Colorado

DENVER -SATURDAY 13 October, 2018

For Private, Commercial, and CFI Glider FAA exam preparation.

Signature Flight Support

Conference Room

BJC - Rocky Mountain Metro, (JEFFCO)
11705 Airport Way, Broomfield, CO 80021

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Private pilot Glider- $180, Commercial or CFI -$200. All books and study material are included in the price.

Private class 8AM-4:30 PM, COM/CFI class 8AM-6PM

Glider Pilots Ground School, established in 1972, and presented for 25 years by Glider Hall of Fame recipient Edgar D. Seymour, has prepared more than 2600 glider pilots for the FAA Glider Knowledge exams. GPGS prepares pilots for the Private, Commercial, and CFI Knowledge and Oral exams in a one day, 8-hour seminar. Their new PowerPoint presentation makes learning fast and easy, and their students have an impressive pass rate for the written exams of better than 99%. The GPGS seminar includes all the information needed to pass the written exam presented in one day. A GPGS text book is included. You will be ready to take the FAA exam 24 hours after the course. Some pilots take it the next day. The course covers Federal Air Regulations - Aerodynamics and Glider Operations - Airman's Information Manual-Airport Directory - Instruments and Systems - Weather-Weather Services - Weight and Balance - Performance - Cross Country Flight Planning - Sectional Chart and Navigation -Radio Navigation - Aeromedical Factors- Decision making - Practice questions and correct responses- and much more. The GPGS books are available for pre-study and for those unable to attend class. They include all the information and all the FAA question banks tailored exclusively for Glider Pilots. The three separate books are available from GPGS at 1-877-FLY-GPGS, online at *gliderpilotsgroundschool.com* as well as from many FBO's and clubs. The course books are great for preparation for the FAA Oral exams, and GPGS carries many products of interest to glider pilots of all experience levels. See the GPGS web site for more information: www.gliderpilotsgroundschool.com. 303-908-3147

Family plan-50% off additional family members attending the same seminar date.

New FAA Questions – Private – June 2018, COM – August 2018, 2014, CFI - July 2018.

KSA Towpilot Directory

If you need a towpilot, contact one of these members:

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Andrew Peters - 316-393-2261 - apsoars@yahoo.com - Limited Availability

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AIRBUS

Press Release

Airbus Perlan Mission II glider soars to 76,000 feet to break own altitude record, surpassing even U-2 reconnaissance plane

Stratospheric glider yielding insights into high-altitude aerodynamics, flight safety and Martian exploration

#AirbusPerlan @PerlanProject #Innovation #AirbusPerlanMissionII

EL CALAFATE, Argentina, Sept. 3, 2018 – For the third time in a week, Airbus Perlan Mission II has set a new world altitude record for a glider, this time soaring the engineless Perlan 2 to 76,124 feet, in the process collecting vital data on flight performance, weather and the atmosphere.

Yesterday's flight by pilots Jim Payne and Tim Gardner surpasses even the maximum recorded altitude in level flight of the U.S. Air Force's famous U-2 Dragon Lady reconnaissance aircraft: 73,737 feet, flown by pilot Jerry Hoyt on Apr. 17, 1989.

The U-2 is powered by an engine that generates 17,000 lbs. of thrust. By contrast, the Perlan 2 is engineless, weighs just 1,500 pounds, and soars to its record altitudes on rare stratospheric air currents formed by mountain winds combining with the Polar Vortex.

"World records are gratifying evidence of progress toward a goal, but the goal itself is advancing our knowledge and expertise," said Tom Enders, Airbus CEO. "By exploring an underexplored part of the atmosphere, Perlan is teaching us about efficient high-altitude flight, about detecting natural sources of lift and avoiding turbulence, and even about the viability of wing-borne exploration of Mars. As a company that makes not just airliners but also high-altitude unmanned aerial vehicles such as Zephyr as well as the Mars rover robotic vehicle, every Perlan flight is an investment in our future."

In a single week, Perlan has set and then surpassed a world altitude record three times:

- Aug. 26, 2018: Jim Payne and Morgan Sandercock soar to 63,100 feet, besting the record of 54,000 feet set by Airbus Perlan Mission II on Sept. 3, 2017
- Aug. 28, 2018: Jim Payne and Miguel Iturmendi reach 65,600 feet
- Sept. 2, 2018: Jim Payne and Tim Gardner climb to 76,124 feet

The overall altitude record for level flight of a manned airplane is held by the SR-71 Blackbird at 85,069 feet. The pressurized Perlan 2 glider is designed to fly to 90,000 feet, conditions permitting.

Airbus Perlan Mission II will continue its 2018 flying season through mid-September, when the season for stratospheric mountain waves in the southern hemisphere begins to die down, and the all-volunteer Perlan Project team will return from Patagonia to homes in the U.S. and around the world. The number of flights remaining will be determined by weather conditions.

Viewers around the world are following Perlan flights live as they occur on the Airbus Perlan Mission II Virtual Cockpit: http://bit.ly/VirtualPerlan2. The Virtual Cockpit shows the glider's altitude, airspeed, remaining oxygen, map position, and even live streaming video from a camera in the tail when the aircraft is in range.

Fans can sign up to be alerted when Perlan is flying at www.perlanproject.org/contact, or in the U.S. by texting "perlan" to 57682. Stay updated on the mission by following The Perlan Project on Twitter @PerlanProject and on Facebook at www.facebook.com/perlanproject.

A Press Kit with images, infographic, fact sheet, and videos is available at: http://bit.ly/perlanpress.

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About Airbus
Airbus is a global leader in aeronautics, space and related services. In 2017 it generated revenues of € 59 billion restated for IFRS 15 and employed a workforce of around 129,000. Airbus offers the most comprehensive range of passenger airliners from 100 to more than 600 seats. Airbus is also a European leader providing tanker, combat, transport and mission aircraft, as well as one of the world's leading space companies. In helicopters, Airbus provides the most efficient civil and military rotorcraft solutions worldwide.

About Airbus Perlan Mission II
Airbus Perlan Mission II is an initiative to fly an engineless glider to the edge of space, higher than any other winged aircraft has operated in level, controlled flight, to open up a world of new discoveries related to high-altitude flight, weather and climate change. This historic endeavor is the culmination of decades of research and engineering innovation, and the work of a tireless international team of aviators and scientists who volunteer their time and expertise for the non-profit Perlan Project. The project is supported by Airbus and a group of other sponsors that includes Dennis Tito, Weather Extreme Ltd., United Technologies and BRS Aerospace.

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Bounded Rationality and Risk Strategy in Thermal Soaring

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Awareness and management of the risk of failing to encounter lift is fundamental to thermal soaring. When the weather changes or a thermal is missed the pilot may be exposed to a greater risk of landing out. In these situations the pilot may need to alter strategies in order to minimize risk exposure at the expense of speed, often referred to as "gear shifting." In this work, we explore several models to explain why small changes in the environment can cause large changes in risk exposure, requiring this shifting. We also examine several flight strategies in simulation to define the relative risk and reward for adopting various levels of risk tolerance and for failing to "shift gears" when the risk of landing out increases.

I. Introduction

Thermal soaring is defined by uncertainty. Even if a pilot can see markers indicating the presence of thermals ahead, it is not certain that a thermal will still be working when the pilot arrives. Managing the risk of failing to find a thermal is an essential component in decision making. In high level competitions, failing to complete a task is often disastrous to a pilot's overall standing in a contest. As a result, pilots must balance their goals of maximizing speed on each glide while minimizing the risk of an outlanding.

While managing risk is key to success in thermal soaring, flight planning and optimization has largely focused on maximizing speed and has not addressed risk explicitly. Since its initial development in the 1930s[1], speed-to-fly theory has been the dominant approach to soaring flight optimization. Paul MacCready's development of the speed ring made the best speed to fly easier to compute in flight[2], and the MacCready setting has since been used both for speed optimization and as a proxy for risk[3, 4]. While most authors examine risk implicitly through the MacCready setting, Fukada finds the risk tolerance which achieves the highest average speed and which scores the most expected points[5]. Fukada only peripherally examines landing out however, and does not consider the approach a pilot would take to achieving a desired risk level[5]. While speed-to-fly theory and adaptations to it are very powerful flight optimization

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tools, they do not provide a pilot a means to manage risk over the course of a flight or competition.

One of the challenges to addressing risk management in soaring is that human decision making is complicated and limited by human capabilities. Thermal soaring is cognitively taxing: there are an inordinate number of possible clouds or thermal sources to sample and every thermal opens up a branching tree of possible choices. Like a chess game, it is nearly impossible to compute all of the possibilities from a given position to determine the right move. Attempting to evaluate all options and make an optimal decision would simply overwhelm the pilot with information[6]. Instead, pilots engage in a number of strategies to omit suboptimal choices which makes the decision-making process manageable. These strategies employ heuristics, mental shortcuts that minimize cognitive workload[7].

In this paper we examine cross-country soaring from the perspective of risk. For our purposes "risk" represents sporting risk – the probability of landing out and no longer having the chance to finish the contest with a good score. We are explicitly not concerned here with risk from the perspective of flight safety: a "failure" ends the flight at a location and situation from which the pilot can make a safe pattern and landing. In this light, failure could also be interpreted as falling out of the lift band and having to "dig out" in a weak thermal, slowing a pilot down enough to preclude a competitive finish.

We seek to understand why risk management is challenging, how sensitive success is to risk, and to define a risk threshold which makes success in competitions likely. We then formulate a model for how humans address risk management, drawing on piloting experience as well as cognitive theory. This leads us to believe that humans bifurcate risk management into two dominant strategies: "racing" and "risk minimization." Selection of a strategy is determined by the reliability and frequency of lift the pilot expects to encounter. Models of these strategies are implemented in numerical simulations to explore the utility of "gear shifting," and the sensitivity of speed and task completion percentage to environmental conditions, risk tolerance, and pilot strategy. This leads us to a model of risk management in thermal soaring which employs simple heuristics in a systematic process that pilots can use to aid their decision making in the cockpit.

II. Assessing Risk Exposure

Before risk can be managed, it must be defined and an appropriate level of risk determined. As we discuss it in this paper, risk is the likelihood of landing out on a glide. In order to study the effect of risk on performance, we are explicitly neglecting variables which are present in reality but which could confound this study. In our analysis, we consider only homogeneous environments with consistent thermal strengths. This permits us to isolate the task of evaluating the risk a pilot is taking and the level of risk that is acceptable to succeed in a contest.

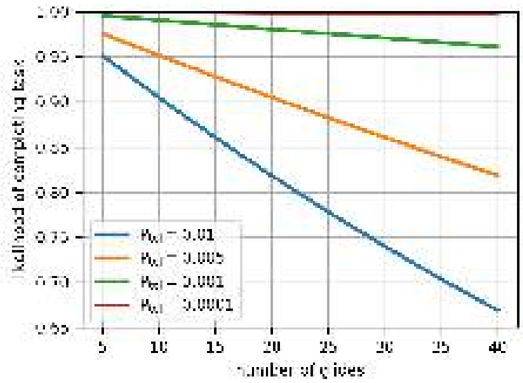


Fig. 1 Probability of completing a task given the number of glides required. The completion probability is shown for several levels of risk tolerance on each glide. For long tasks, the probability of completion is very sensitive to the risk tolerance, and even seemingly low risk tolerances can result in a significant probability of landing out.

A. Strategic Risk

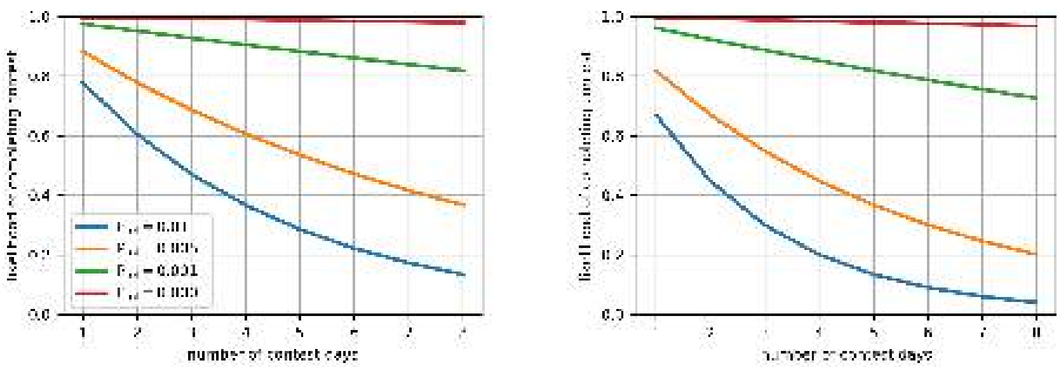
Considering the risk of landing out, one can think of each glide as an independent event; a gamble with a probability of finding a climb (success) or landing out (failure). Looking at a contest day, we can consider the sequence of glides required to complete the task and compute the cumulative probability of success. Similarly, a contest is a continuation of such sequences. As such, the risk one accepts on each glide is compounded by the number of glides taken over a contest.

This raises the question: "what level of risk should a pilot try to maintain in order to succeed in a contest?" To answer this question, we assume that most competitors complete each task. This is commonly the case at competition sites with strong and consistent weather; such as in the western USA, Australia, or South Africa. In such contests, it is genuinely possible to tune risk preferences and maintain them over the course of a contest. In places with highly volatile weather, the immediate tactical situations predominate in a pilot's decision making; when a pilot is simply concerned with staying airborne, strategic concerns become less relevant.

To determine an appropriate risk baseline, we first compute the likelihood of completing a contest day without landing out. We assign an accepted risk of landing out on each glide, P_{tol} = {0.01, 0.005, 0.001, 0.0001}. Figure 1 depicts the cumulative risk of landing out in a single contest day for several task lengths. This risk can be computed using Equation 1 where n is the number of glides required.

$$P_{success} = (1 - P_{tol})^n \tag{1}$$

It is apparent that very small changes in risk tolerance, perhaps imperceptible other than through long-term feedback,



(a) Probability of completing a contest without landing out assuming each contest day requires 15 glides to complete.

(b) Probability of completing a contest without landing out assuming each contest day requires 25 glides to complete.

Fig. 2 Probability of completing a contest without landing out for two different task lengths. As the contest and task length grows the level of acceptable risk shrinks.

have a very large impact on the likelihood of completing a task. A pilot that flies 15 glides on a contest day and has a risk tolerance of 1% only has an 86 percent chance of completing a task!

B. Cumulative Effect of Risk Over a Contest

To win a contest requires consistent performance over multiple contest days, further compounding the risk of failure. Assuming pilots maintain a consistent risk profile and fly 15 glides per contest day, the probability of completing the contest without landing out can be computed. This relationship is depicted in Figure 2a; in a five day competition a pilot flying at $P_{tol} = 0.01$ would have less than a 50 percent chance of completing the contest without landing out.

For longer tasks, such as in World Championships and competitive National competitions, the effect is even more striking. If we increase the number of glides flown per day to 25, even less risk is acceptable, as depicted in Figure 2b. For pilots flying at $P_{tol} = 0.01$, the likelihood of completing without landing out over a five-day competition falls to 30 percent.

This motivates the concept of a "strategic baseline" risk – a level which provides a good chance of completing every day of a competition without landing out. Figure 2 indicates that for this simple analysis, the strategic baseline risk per glide is about 0.001.

It is important to distinguish at this point between the strategic baseline and risk tolerance, P_{tol}. The strategic baseline represents a risk level which is likely to provide good results in a contest, while the risk tolerance represents the level of risk a pilot actually accepts when planning a glide. While they are nominally the same, there are instances where a higher or lower tolerance is preferable. For instance, Figure 2 can also be examined from the perspective of the number of days remaining in a contest. On the last two days of the competition, a pilot may actually be prudent shifting to $P_{tol} = 0.005$ or even $P_{tol} = 0.01$ as the likelihood of finishing without landing out at this point is 80 to 90 percent.

When discussing risk tolerance, it is important to recall the gambler's fallacy; gambles have no memory! A pilot who "survives" a series of unlikely gambles on a given day should not be extraordinarily risk averse on the following days to help "replenish his luck." However, if the risks taken give the pilot a clear edge in points, it may be sensible to adopt a low risk tolerance to help protect the pilot's gains.

C. Tactical Risk

How can we estimate how much risk to accept while in the cockpit? Let us consider a pilot who is at the top of the lift band, assessing the thermal options ahead. The pilot picks a line and counts the number of potential thermal sources that can be sampled before running out of altitude and landing out. While a thermal source can be either a cloud or a particularly promising ground feature, we will refer to all options as "clouds" as they are simpler to visualize. Days with cumulus clouds are also useful since a cloud field often will give a fairly good picture of the amount of thermals one can possibly contact. Despite the fact that as the pilot gets lower the thermals are less likely to be connected to the clouds, the number and quality of clouds can still provide feedback as to the reliability of thermals in an area.

Each thermal option can be thought of as either a "hit" or a "miss," just like "heads" or "tails" when flipping a coin. This assumes that each thermal sampled is independent of the rest. There are circumstances that violate this assumption, such as on days with cloud streets, cirrus bands, or convergence lines. However, on days with "popcorn" cumulus and little wind, we believe it is reasonable to assume that thermals are largely independent of each other.

Continuing our coin toss model, a pilot unlucky enough to flip tails for each cloud sampled will land out. We can calculate the probability of a completely failed sequence and then compare it against a strategic baseline of $P_{tol} = 0.001$. So long as the pilot consistently keeps the likelihood of flipping all tails lower than $P = 0.001$, he or she is likely to complete a competition without landing out.

Without any experience other than occasionally encountering thermals underneath clouds, a pilot may expect that finding a thermal is really like a coin toss – 50/50. We can determine how many options are required to achieve a chosen risk tolerance, depicted in Figure 3. In order to maintain $P_{tol} \leq 0.001$, the pilot would need to keep at least ten clouds in range at all times. Note how little the risk changes for a pilot flying "aggressively" with only four clouds to sample as opposed to ten. In the short-term, a pilot who chooses this strategy may even be successful.

However, very small changes in risk exposure have a massive cumulative impact in the long run. The difference in risk accepted from having only seven clouds to ten clouds in a sequence with a fair coin is only one tenth of one percent. On a given contest day, this cannot markedly feel all that different. However, over an eight-day competition with 25 glides per day, this amounts to a 69 percent difference in the probability of completing without landing out!

Experienced pilots know that the likelihood of hitting a thermal under a cloud can be more predictable than a simple coin toss. If the pilot was routinely hitting thermals under clouds, she can reasonably believe that most of the clouds

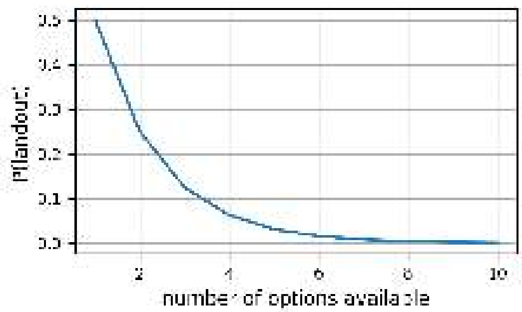


Fig. 3 Number of thermal options required to achieve a desired risk tolerance assuming that each potential thermal source sampled has a 50% chance of working

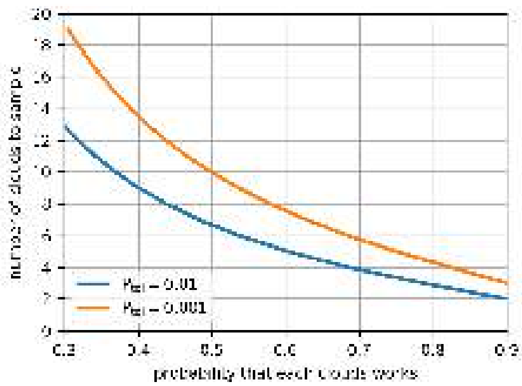


Fig. 4 Number of clouds required to maintain a specified risk tolerance as a function of the probability that each potential thermal works.

ahead are "working." Finding lift is not a certainty however, there is the possibility that a promising cloud dissipates or that the pilot misjudges the thermal location and misses a climb. Furthermore, there are days when the clouds are "dishonest" and the prudent pilot realizes that she must sample many more clouds before contacting a thermal. To incorporate the expected "honesty" of the clouds, we can use a weighted coin model:

$$n_{options} = \frac{\log(P_{tol})}{\log\left(1 - P_{option\ works}\right)} \tag{2}$$

.

The number of clouds required to maintain a safe strategic risk profile is depicted in Figure 4. Since the honesty of clouds controls the number of options required, there is a strong emphasis on the degree to which clouds are working. Once the probability of contacting a thermal under a cloud is less than 50%, it becomes nearly impossible to maintain the strategic risk baseline. Once the probability that thermals work exceeds 70%, the number of options the pilot must

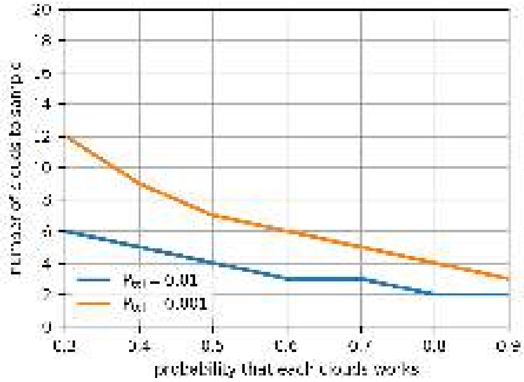


Fig. 5 Number of clouds required to maintain a desired risk tolerance as a function of the probability that each potential thermal works, assuming that one thermal with a 95% chance of working is known (e.g. a power plant, or a gaggle-marked thermal).

maintain becomes considerably more manageable. The risk is non-linear; when the days are "consistent" and "reliable," the pilot can afford to have few options available and still have a very low probability of landing out. On the other hand, as the reliability of the lift diminishes, the pilot must maintain many more options in order to maintain an acceptable strategic risk exposure.

On a tactical level, maintaining even one "very likely" thermal option can significantly reduce a pilot's risk exposure. If the pilot looks ahead and realizes that in his sequence of clouds to sample, there is one source that has a 95 percent chance of working; the likelihood of landing out on the whole sequence is much lower. Pilots who are especially good at reading ground sources or clouds can factor this in their tactical choices. Equation 2 can be modified to take into account one very likely cloud:

$$n_{options} = \frac{\log(P_{tol}) - \log\left(1 - P_{likely\ option\ works}\right)}{\log\left(1 - P_{option\ works}\right)} \tag{3}$$

The number of clouds required to achieve a desired risk tolerance is considerably reduced, depicted in Figure 5.

III. Modeling Pilot Decision Making

Now that we have a broad sense of how the quantity and reliability of thermals affect risk both in the long run of a whole competition and in the short run of a glide, the challenge is to model this decision making in terms that can be applied in the cockpit. Recognizing that it is *humans*, not computers which make decisions in soaring competitions, we must consider how people manage risk and make decisions under uncertainty when we develop risk management strategies.

A. The Brain as a Computer

While the brain is not a computer, it shares some basic characteristics with them: it processes inputs from the environment through the body's senses, integrates this data into perceptions, and generates a motor-driven output (i.e. moving the stick). The brain as an information processing unit has extraordinary capabilities but also significant limitations. Cognitively, one of the greatest limitations is working memory, limited to approximately 30 bits[8]. On the other hand, the brain has nearly endless capacity for long-term memory[9].

As a result, the brain is very effective at using long-term memory as a work-around for the limitations of working memory. Over time, the results of favorable computations become encoded and are retrieved given the right pattern of inputs. When a pilot identifies a cloud as particularly favorable, it is the result of having flown under many similar clouds with good outcomes. Thus, the brain offloads most cognitive tasks to programs or schemas of action; when there is a set of stimuli, to generate a certain output. It is through this process that many tasks become largely automatic or intuitive; the brain no longer needs to engage effortful cognitive processing in order to generate a good output.

Heuristics, or rules of thumb, are processes the brain uses to simplify the decision-making process[10]. For instance, a simple risk-related heuristic is to take every thermal on a cross country task. By taking every thermal, decision making is drastically simplified and the pilot is unlikely to land out. With experience, pilots refine and expand their heuristics, encompassing more and more variations in the environment.

Often, the goal is to make a good decision, not necessarily the best decision. Doing so is referred to as "satisficing"[11]. This permits acceptable outcomes while reserving cognitive capacity for other tasks. A sophisticated form of satisficing which pilots likely use is "elimination-by-aspects," which employs successive heuristics to exclude clearly suboptimal solutions[12]. For instance, in choosing the next cloud, a pilot may use criteria such as: "don't deviate more than 30 degrees", "fly under the clouds", "fly MC 1 (m s^{-1}) and stay on the upwind side of the course." By engaging these heuristics in sequence, the pilot can very quickly narrow down a large field of potential thermals to several "lines," saving the trouble of processing every single cloud and its respective decision tree.

B. Decision-Making Frames

While the elimination-by-aspects strategy helps pilots rapidly make decisions, the sets of heuristics employed can vary by situation. The heuristics a pilot uses when struggling at low altitude trying to "minimize risk" on a blue day are distinct from the heuristics used when at altitude, cloud streets are plentiful, and the pilot is "racing". Pilots choosing to engage their "risk minimization" program will process their environment differently than pilots engaged in "racing." These programs and the heuristics associated with them are called "decision-making frames."

The way in which frames are managed depends on how a pilot appraises his tactical situation and what losses are most immediate in his mind. In gliding, pilots are conflicted between two kinds of losses: losses in speed relative to competing pilots, and the catastrophic loss of landing out. Since people are averse to losses[13], the manner in which losses are processed will greatly affect decision making. When facing an uncertain gamble that is framed as a choice among losses, people tend to overweight the impact of a loss[14, 15]. This is known as loss aversion, a phenomenon described by prospect theory[16].

Depending upon whether losing efficiency or landing out weighs more heavily in a pilot's mind will determine whether that pilot will make decisions from a racing or risk minimization frame. This is because the pilot evaluates gains and losses relative to the most salient loss in her mind[9]. Framing refers to the manner in which costs/benefits or risks are presented and interpreted. For instance, the likelihood a patient accepts a treatment is affected by whether he is told by his doctor that a treatment has a 95 percent survival rate, or that 1 in 20 people die, despite both options being mathematically equivalent. In gliding, when a pilot adopts a risk minimization frame, any action that increases the pilot's risk of landing out is experienced as a greater loss. When a pilot is in a racing frame, any action that diminishes speed is experienced as a loss. This is what drives a pilot to leave a thermal when a competitor merely bumps through it and continues: it is painful to give up points!

When a pilot's losses are reframed, such as when a pilot gets lower and becomes more concerned with the prospect of landing out than maximizing efficiency, the heuristics that are used in decision making change. Under the same conditions, the same pilot can generate distinctly different outputs depending on the decision-making frame adopted. This frame shift is the core of gear shifting; when the availability and reliability of lift dictate that a pilot must shift into a risk minimizing frame, the pilot who shifts earlier is more likely to make it home. If conditions change from unreliable to reliable, the pilot who shifts into racing will fly faster.

For the present work, we define models of these two decision-making frames and their respective heuristics for further analysis. This will enable us to explore the effect that the frames have on the speed a pilot achieves and how effective frame switching can be in managing risk in competition soaring.

1. Racing

The first behavior we call the racing frame. In this mode the pilot seeks to maximize speed while attempting to maintain a chosen risk tolerance. Diverting the flight path and stopping to thermal both decrease average speed, so the pilot will avoid these actions when possible. In a racing frame, the pilot will reevaluate the flight plan if an anticipated thermal fails to work, but will continue on a path that minimizes deviations and maintains a high speed. The pilot will attempt to satisfy a risk tolerance, but will not make large deviations or slow down to do so.

When racing, the flight path is generated using an iterative method which is initialized with a direct flight to the next turnpoint. Thermals are added to the flight plan until the number of thermals is sufficient to satisfy the acceptable risk of landing out. At each iteration, the longest leg between potential thermals is rerouted to visit another potential thermal (following a heuristic that failing to find a thermal after the longest glide will leave the pilot at the lowest altitude and is thus the most likely to cause a landout). The closest thermal which is in range along that leg is added to the plan. This

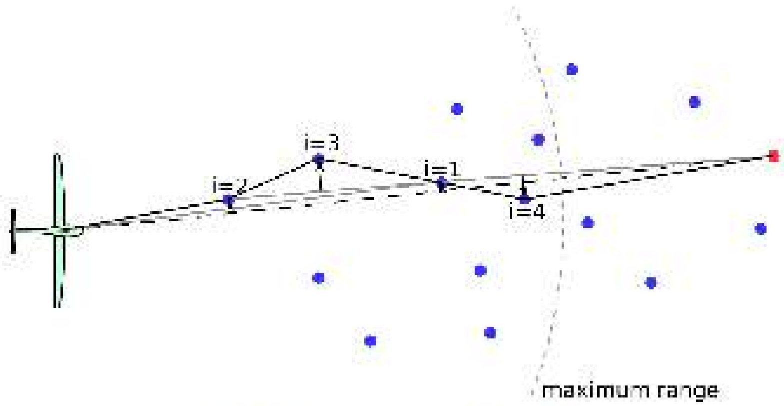


Fig. 6 Path planning method for a pilot in the racing frame. The pilot starts with a direct glide to the next waypoint (dashed line leading to the red point) and at each iteration choses the thermal (blue points) nearest the longest segment of the path. This process is repeated until there are no thermals remaining in range or until the desired risk tolerance is met. The pilot is assumed to be able to detect any possible thermal within gliding range. The thermal added to the path at each iteration is depicted by iteration number and intermediate paths are shown in gray.

is repeated until the plan satisfies the risk constraint or until there are no more thermals within range. The planning model is intended to identify "lines" of favorable conditions, as illustrated in Figure 6.

When planning, the pilot is assumed to be able to predict the approximate location of any thermal within range (with a standard error of 400 m). When nearing a thermal, the pilot can determine the precise location and whether or not the thermal is working when within 700 m of the thermal center. When the pilot encounters a thermal, the planning model is run again and if the risk tolerance can be met from the current altitude then the thermal is skipped. If the risk tolerance is exceeded by skipping the thermal then the pilot stops to exploit the thermal. In all cases, thermals are not exploited if the current altitude is more than 80% of the boundary layer depth.

If a thermal is encountered which does not work, the pilot will replan the flight path from the current location. While the pilot attempts to keep the probability of landing out below the desired risk tolerance via planning, no action is taken if the risk rises above this level (i.e. if there are not enough thermals in range to allow the tolerance to be satisfied).

2. Risk Minimization

A second behavior is implemented where the pilot is primarily concerned with remaining aloft, but also desires to complete the task. We call this the risk minimization frame. In this frame, the pilot will seek out any lift which brings him closer to the next turnpoint, and will exploit any thermal encountered below 80% of the maximum altitude.

Again, the pilot can detect any thermal in range, and can determine if the thermal is working when within 700 meters. The pilot chooses as a destination the nearest thermal which brings the pilot closer to the waypoint. The pilot exploits that thermal if it is working or repeats the thermal selection process if the thermal does not work. The path

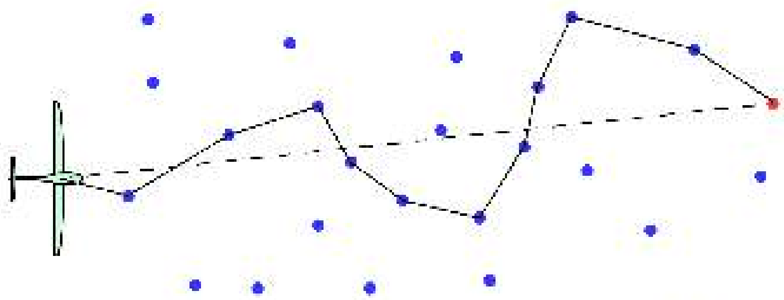


Fig. 7 Path planning for a pilot in the risk minimization frame. The pilot will fly to the nearest thermal option (in blue) which brings the pilot nearer to the next turnpoint (red). The pilot will accept large deviations to minimize the distance which must be flown before encountering a potential thermal.

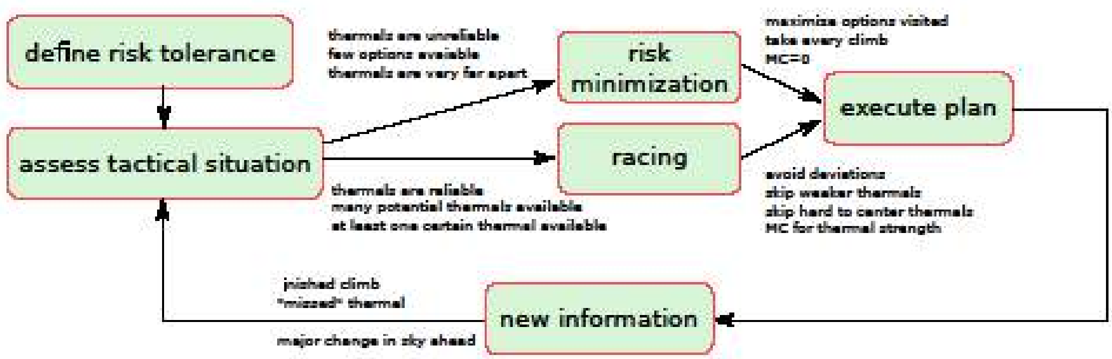


Fig. 8 Schematic describing the decision-making process for risk aware thermal soaring. Gear shifting occurs when the pilot receives new information which reveals a change in the risk situation and reevaluates the decision-making frame. This could happen for example when missing an expected climb or when reaching a "blue hole" with few clouds.

planning strategy in risk minimization mode is depicted in Figure 7.

C. A Summary of The Decision-Making Process

Figure 8 illustrates the decision-making process we present here. Selection of the risk tolerance is described in Section II.A. Assessment of the tactical situation is described in Section II.C. Section III.B describes an approach to managing tactical risk which is rooted in the psychology of human decision making. At each step in the decision-making process heuristics are employed which reduce the cognitive load on the pilot and allow this schematic to be traversed rapidly in flight. The heuristics employed in this work are summarized in the flowchart.

IV. Monte Carlo Simulations

The coin toss model motivates the need for risk management and the psychology perspective introduces the concept of decision-making frames. This provides insight into the why and how of risk management but these approaches do not lend themselves well to analysis of flight to turnpoints, in limited altitude bands, or in the vicinity of areas of inhibited lift. To enable deeper exploration of risk strategy in thermal soaring, we used a Monte Carlo approach.

Pilot behaviors representing the racing and risk minimization frames are implemented in a numerical simulation. A configurable frame-switching logic is implemented which permits allowing or prohibiting switching between frames. These pilot behaviors are then simulated over several hundred competition tasks to evaluate the effect of risk tolerance and frame switching. This is conceptually similar to work done by previous authors[3, 4] except that we explicitly explore the pilot's risk tolerance rather than using MacCready setting as a proxy.

A. Simulation Environment

Thermals are defined using a Gaussian model:

$$w = w_{scale} \exp\left(\frac{-r}{R}\right) \tag{4}$$

Where r is the distance between the aircraft and the thermal center, R is the characteristic scale of a thermal, and w_{scale} is the maximum updraft velocity. At altitudes above the boundary layer top the thermal updraft velocity is set to zero.

Candidate thermal locations are drawn from a uniform distribution $\mathcal{U}(x_{scale})$. A weighting function is then applied to prevent thermals from occurring extremely close to each other. The weight is defined:

$$\theta_{inhibit} = \frac{1}{1 + \exp\left(-w(X_{candidate}) + 0.1\right)} \tag{5}$$

Where $X_{candidate}$ is the candidate location for a new thermal and $w(X_{candidate})$ represents the thermal updraft velocity at the candidate location due to any thermals already accepted into the updraft field. The factor 0.1 is used to allow thermals to slightly overlap, forming multi-core thermals. A uniform random thermal acceptance probability is generated, if it exceeds the weight then the thermal is accepted and added to the field. The parameters of each thermal are summarized in table 1. At generation, each thermal is assigned a working or not working state with a configurable probability.

Table 1 Parameters of the thermals used in the Monte Carlo simulations. The thermal strength is kept constant to isolate the effect of risk management and to simplify computation of the appropriate MacCready number. Approximate conversions to common U.S. units are given in the second column.

R	$\mathcal{N}\left(600\text{ m}, 10000\text{ m}^2\right)$	$\mathcal{N}\left(2000\text{ ft}, 100000\text{ ft}^2\right)$
w_{scale}	3.0 m s^{-1}	6 knots
z_i	1000 m	3300 ft

The aircraft model is a simple kinematic model whose states are the east, north, up position of the aircraft and the heading angle. Inputs to the system model are turn rate and airspeed. Lateral dynamics are neglected (the commanded turn rate is achieved instantly) and the longitudinal aircraft dynamics are simulated with a first order lowpass filter on the airspeed command with a time constant of 5.0 s. The aircraft dynamic equations are summarized in equation 6.

$$\frac{\partial}{\partial t}\begin{bmatrix} x_{east} \\ x_{north} \\ h \\ \psi \end{bmatrix} = \begin{bmatrix} v_{east} \\ v_{north} \\ \dot{h} \\ \dot{\psi} \end{bmatrix} = \begin{bmatrix} v_{ias}\sqrt{\sigma}\sin\psi \\ v_{ias}\sqrt{\sigma}\cos\psi \\ w_s(v_{ias})\sqrt{\sigma} + w_{wind} \\ \dot{\psi} \end{bmatrix} \tag{6}$$

Where $\dot{\psi}$ is the commanded turn rate and σ represents the ratio of sea level density to the density at the aircraft location, computed using the 1976 standard atmosphere model. A quadratic speed polar is used to represent the sailplane's aerodynamic performance, given in equation Equation 7. The polar approximates a Discus 2 at a wing loading of 35 kg m^{-2} (airspeed and sink rate are both specified in m s^{-1})

$$w_s(v_{ias}) = -0.00285\, v_{ias}^2 + 0.146\, v_{ias} - 2.51 \tag{7}$$

B. Pilot Model

A pilot model is implemented which incorporates both basic airmanship and risk-based decision making. The airmanship portion is responsible for controlling the sailplane. A higher-level model implements the behaviors described in Section III.B.

1. Airmanship: Airspeed Selection and Trajectory Tracking

It is necessary to simulate the pilot's behavior in controlling the speed and direction of the aircraft. Airspeed commands are generated using speed-to-fly theory, with the MacCready setting determined by the pilot's frame. In the racing frame, the MacCready value is set to the climb rate achieved given the thermals defined in Table 1. In the risk minimization frame the MacCready setting is zero to maximize range. To represent the response time of the pilot and aircraft, the airspeed command is filtered with a first order lowpass filter with a time constant of 5.0 seconds. The filtered airspeed command is directly used in the aircraft state equations.

Trajectories for the pilot are defined as a series of points to visit, with each point being either a turnpoint or a potential thermal. The trajectory generator depends on the pilot frame as described in Section III.B. To follow the path, Park's nonlinear trajectory following controller[17] is used to generate turn rate commands. When thermalling the pilot tracks a circular orbit around the thermal location.

2. Risk Management Strategy

In order to determine the effect that frame shifting can have, two approaches to risk management are implemented. The first attempts to optimize the flight at a given risk tolerance at all times. While the pilot plans a path which seeks to maintain a given strategic baseline risk, it is not guaranteed that this threshold can be met at all times. This pilot will remain in the racing frame regardless of risk, pressing ahead at all times. In the simulation results this is referred to as the "racing" strategy.

The second pilot behavior switches frames depending on the current risk. The pilot continuously monitors the risk of landing out. If the risk rises above the pilot's risk tolerance, the pilot will switch frames into risk minimization mode in an attempt to mitigate the risk of landing out. This mixed approach is called the "gear-shifting" strategy.

C. Results

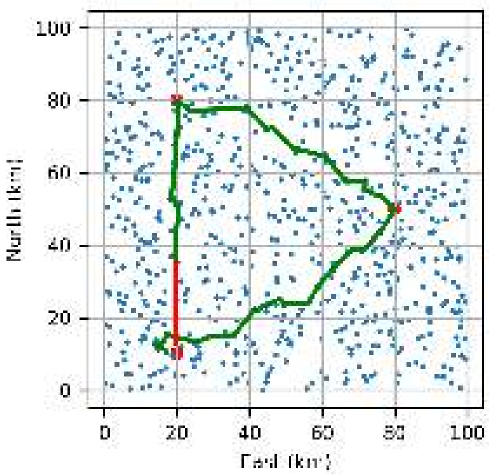
Pure racing and gear shifting strategies are simulated for 350 iterations of a triangular assigned task 220 km in length. The start and finish cylinders each have a radius of 3 km, while turnpoints have 500 meter radii. The thermal reliability is varied ($P_{thermal\ works} = \{0.4,\ 0.7\}$) and several risk tolerances ($P_{tol} = \{0.1,\ 0.05,\ 0.01,\ 0.001\}$) are studied.

Figure 9 compares the flight path and altitude profile for gear shifting and non gear shifting pilots at a risk tolerance of 0.001 and for a thermal reliability of 0.7. Over small segments the flight paths of the two pilots are similar. However, when one pilot switches into risk minimization mode significant differences arise. When entering a tricky area, especially after missing a thermal, the gear-shifting pilot will occasionally make large deviations to remain connected with lift. At times, gear shifting occurs immediately upon finishing a climb if a path cannot be found that satisfies the risk tolerance. Gear shifting can also be triggered when an expected thermal fails, for example in Figure 9d at $t \approx 3000\ s$ (approaching the first turnpoint in Figure 9b). In this case, the pilot seeks a climb, trying several potential thermals before locating one.

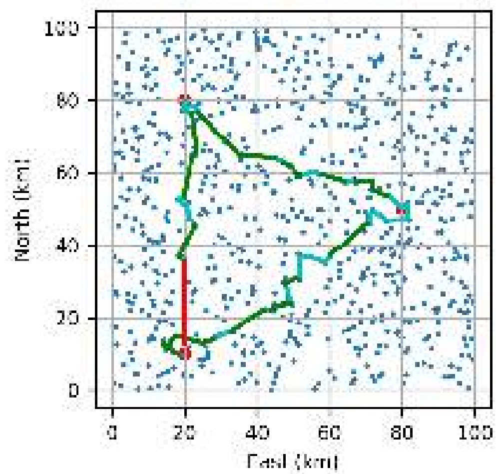
Figure 10 compares the effect of two different risk levels on the flight path and altitude band used when conditions are inconsistent (thermals have a probability of working of 0.4) with no gear shifting. The more risk tolerant pilot typically uses more of the altitude band and flies a relatively direct course. The risk averse pilot makes large deviations to try to maintain the chosen risk tolerance, especially when a planned thermal does not work.

V. Discussion

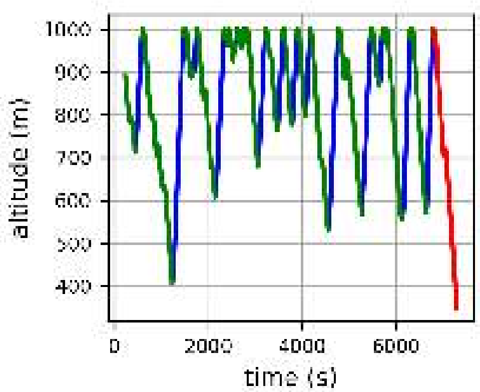
The Monte Carlo simulations provide a means to evaluate the effect of risk management techniques and risk tolerance while navigating a task with altitude constraints. In particular, the simulations can reveal the effect of flight strategy on the probability of landing out and on the speed achieved on course.



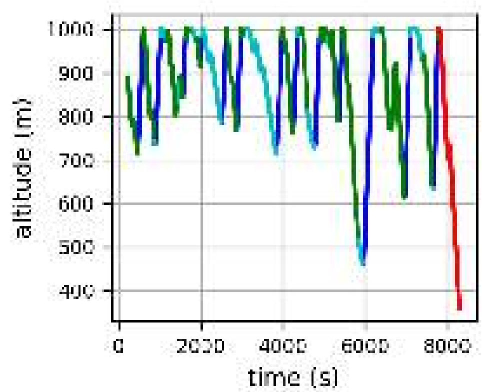
(a) Sample flight path for a pilot who remains exclusively in the racing frame.



(b) Sample flight path for a pilot who shifts between racing and risk minimization frames.

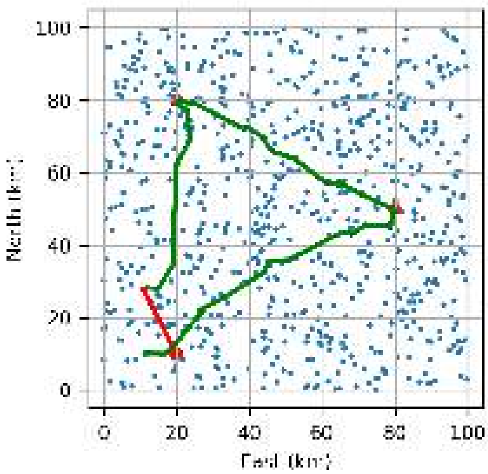


(c) Sample barogram for a pilot who remains exclusively in the racing frame.

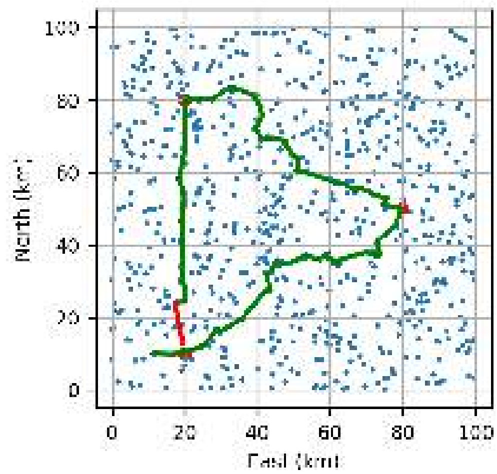


(d) Sample barogram for a pilot who shifts between racing and risk minimization frames.

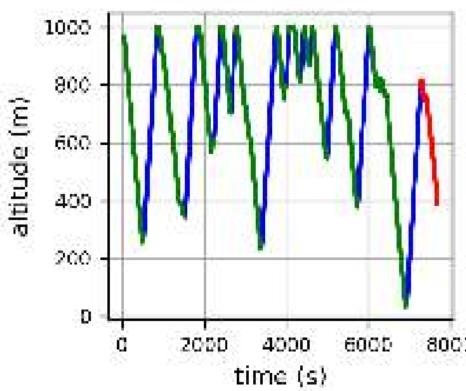
Fig. 9 Effect of gear shifting on flight path and altitude utilization for a pilot with a risk tolerance of 0.001 with reliable thermals (probability of working is 0.7). Thermalling is depicted in blue, racing in green, risk minimization in cyan, and final glide in red. Potential thermal sources are depicted as blue dots and turnpoints as red dots. The task starts at n=10 km, e=10 km and proceeds anti-clockwise.



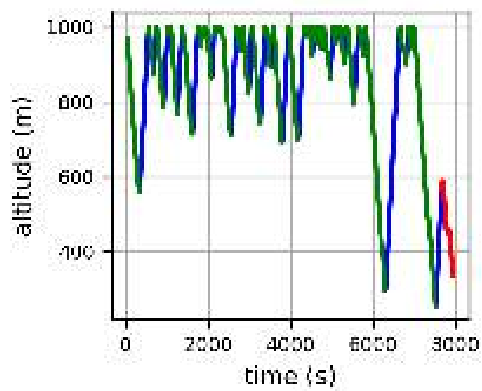
(a) Sample flight path for a pilot flying with $P_{tol} = 0.1$



(b) Sample flight path for a pilot flying with $P_{tol} = 0.01$

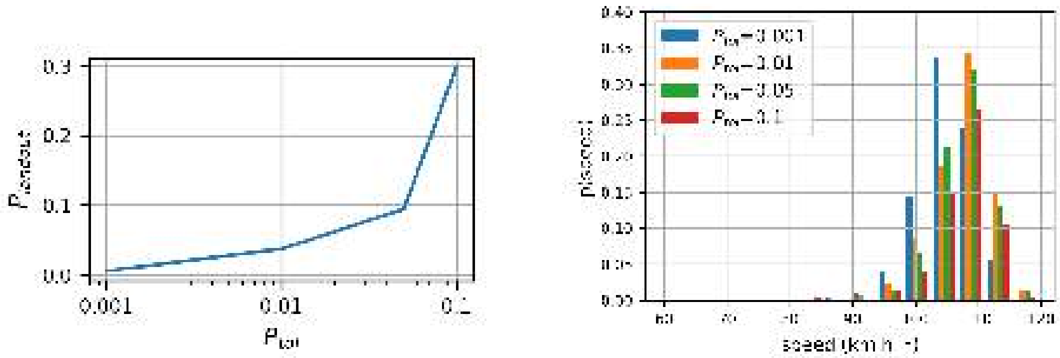


(c) Sample barogram for a pilot flying with $P_{tol} = 0.1$



(d) Sample barogram for a pilot flying with $P_{tol} = 0.01$

Fig. 10 Effect of risk tolerance on flight path and altitude utilization with unreliable thermals (probability of working is 0.4) for pilots always in the racing frame. Colors and task are as in Figure 9.



(a) Probability of failing to complete a task when the probability that a given thermal works is 0.7, the horizontal axis is plotted on a log scale.

(b) Average cross-country speed distributions when the probability that a thermal works is 0.7

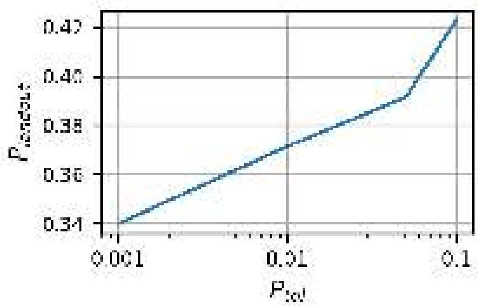
Fig. 11 Probability of task completion and mean cross-country speed when thermals have a 70% chance of working and the pilot remains in the racing frame at all times. In consistent conditions, the pilot can achieve small rates of landing out in a pure racing frame with relatively small risk tolerances. Further, small risk tolerances are associated with only moderate reductions in average speed.

A. Effect of Risk Tolerance on Mean Speed and Probability of Task Completion

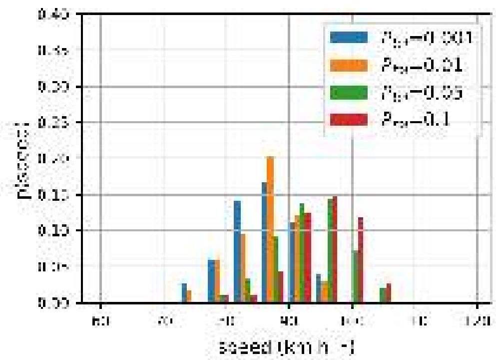
When conditions are consistent, risk tolerance and mean speed are not strongly related over a broad band of risk tolerance. Figure 11b shows that similar speeds are attained for risk tolerances between 0.01 and 0.1 when thermals have a probability of working of 0.7. This is likely because in consistent conditions only a few more potential climbs can significantly decrease risk, minimizing the deviation required. Only at $P_{tol} = 0.001$ does risk tolerance significantly affect the shape of the average speed distribution. The 0.001 level is what we identified as an appropriate "strategic risk baseline." This explains why sailplane racing is such a challenge: at the strategic baseline risk, both speed and probability of landing out are sensitive to the risk tolerance, so the pilot must walk a careful line between flying efficiently and landing out.

Figure 11a shows that even when the mean speed is unaffected, risk tolerance has a substantial impact on the probability of finishing the task. The risk of landing out is lower than suggested in Section II.A. This is because when a thermal is missed, the pilot creates a new plan which attempts to maintain the desired risk level.

When conditions are unreliable, risk tolerance controls speed much more strongly. Figure 12b shows that the speed distribution varies progressively as a function of risk tolerance when thermals have only a 40% chance of working. Reducing risk in unreliable conditions requires many thermals, keeping this many thermals in range can require large deviations. This is illustrated in the sample flight paths in Figure 10. The most striking result is that when thermals are unreliable, the risk of landing out is very large. Even for a per-glide risk of 0.001, the pilot lands out about 30% of the time. This indicates that it is often impossible to keep enough thermals in range to achieve this risk level.



(a) Probability of failing to complete a task when the probability that a given thermal works is 0.4. the horizontal axis is plotted on a log scale.



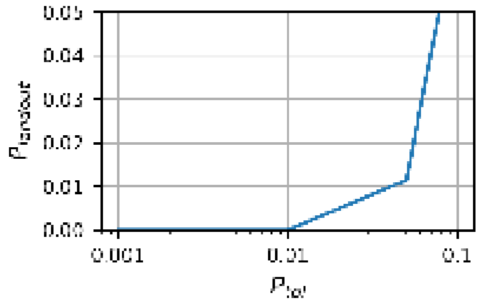
(b) Average cross-country speed distributions when the probability that a thermal works is 0.4

Fig. 12 Probability of task completion and mean cross-country speed when thermals have only a 40% chance of working and the pilot remains in the racing frame at all times. In unreliable conditions, the probability of landing out in a pure racing frame is unacceptably high, greater than 30%. The probability of landing out is considerably higher than Figure 1 suggests, this indicates that it is often impossible to maintain enough options to satisfy any risk tolerance.

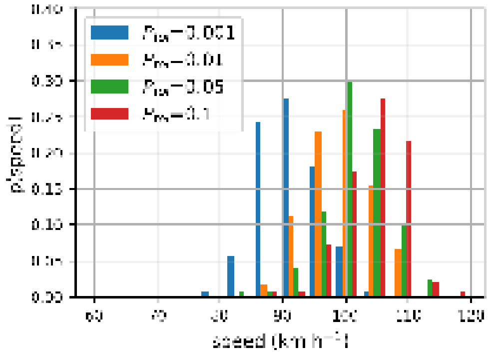
B. Impact of Gear Shifting Strategy

Unsurprisingly, gear shifting reduces the risk of landing out considerably. Figure 13a shows that by changing frames, the chance of landing out is reduced for every risk tolerance. Under consistent conditions (potential thermals worked with 70 % probability) not a single pilot landed out in 350 task simulations for risk tolerances of 0.01 and 0.001. The risk reduction in gear shifting comes at the expense of speed however. Figure 13b shows that speeds are reduced by more than 5 km h^{-1} for each risk tolerance. In fact, depending on the acceptable risk of landing out on a contest day, it may be advantageous to abandon gear shifting. For example if the acceptable risk of landing out is 5% (perhaps reasonable on the last day of a close contest), the pilot can achieve a higher speed by adopting a risk tolerance of 0.01 but staying in the racing frame than by flying very aggressively (risk tolerance of 0.1) and using gear shifting.

The effect of gear shifting in unreliable conditions is illustrated in Figure 14. The most obvious effect is that it reduces the probability of landing out by approximately a factor of 10, from greater than 30% to less than 3%. Comparing Figure 13a and Figure 14a we can see another interesting effect: the gear-shifting pilot has a lower risk of landing out in unreliable weather than in consistent conditions at high risk tolerances (P_{tol} = 0.01). The reason for this is likely three-fold. First, in unreliable weather the pilot will almost always take any thermal encountered, as skipping a thermal would violate her risk tolerance. Second, it takes very little to drive the pilot into a risk minimization frame, so when a thermal doesn't work the pilot is on average higher in energy and has more freedom of action to mitigate the risk. Third, in reliable weather the pilot will fly with fewer options at a given risk tolerance so the loss of one thermal can sharply increase the risk of landing out.

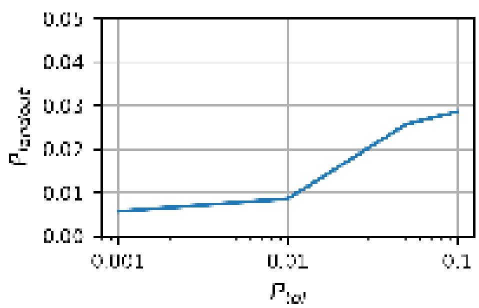


(a) Probability of failing to complete a task when the probability that a given thermal works is 0.7 and the pilot can shift gears. The horizontal axis is plotted on a log scale.

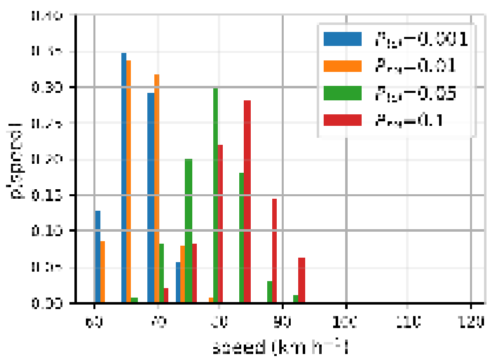


(b) Average cross-country speed distributions when the probability that a thermal works is 0.7 and the pilot can shift gears.

Fig. 13 Probability that the pilot fails to complete the task and the speed distribution for a pilot who can shift gears. Gear shifting can substantially reduce the likelihood of landing out, at the expense of some speed. For smaller risk tolerances not a single pilot in 350 tasks landed out.



(a) Probability of failing to complete a task when the probability that a given thermal works is 0.4 and the pilot can shift gears. The horizontal axis is plotted on a log scale.



(b) Average cross-country speed distributions when the probability that a thermal works is 0.4 and the pilot can shift gears.

Fig. 14 Probability that the pilot fails to complete the task and the speed distribution for a pilot who can shift gears. Gear shifting again substantially reduces the risk of landing out, in this case by more than a factor of 10. In some cases, the pilot is actually less likely to land out than when gear shifting in reliable conditions.

Interestingly, while the risk of landing out is not dramatically different across risk tolerances, the mean speed varies considerably with risk tolerance in unreliable conditions when the pilot can shift gears, depicted in Figure 14b. This is likely because the deviations required to keep a low risk level are considerable. The effect would indicate that in unreliable conditions the pilot should take bigger risks on glides but aggressively switch into a risk minimization frame if a planned thermal does not work out.

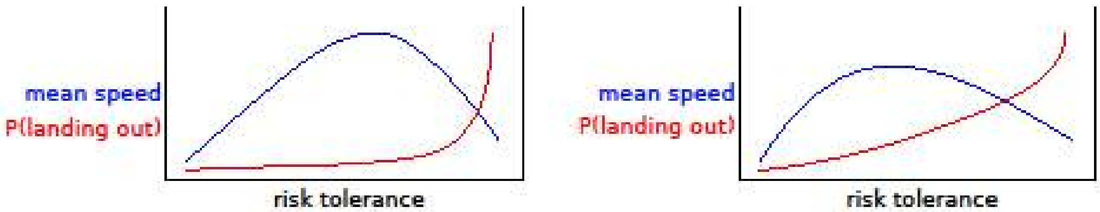
VI. Interaction of Risk and Reward

Throughout the paper so far, we have focused exclusively on risk as a driver of decision making in thermal soaring. From this perspective, behaviors bifurcate into two distinct frames. The existence of these frames is supported by risk-management psychology and the experience of many cross-country pilots who frequently discuss "switching gears". Simplifying these behaviors to their cores permits us to determine the effect these behaviors can have on the risk of landing out and on speed, but in some cases these behaviors are not so distinct.

When the objective is to maximize speed while completing a contest (rather than exclusively keeping risk below a desired level), the pilot will no longer fly the "pure" version of these frames and will adjust her outputs accordingly. In the real world, even when pilots are in a racing frame, they are still somewhat concerned with the risk of landing out. Furthermore, even when a pilot is in a risk minimization frame, she will still consider how her choices will affect her speed. As such, we are proposing a model of decision-making in which a pilot chooses a frame (racing or risk minimization) and runs its respective heuristics. Once the output is generated, the pilot will adjust the result depending upon the risk/reward of the tactical situation.

As we demonstrate in Section II, the probability of landing out is controlled by risk tolerance. Section V.A demonstrates that speed is also sensitive to risk. We can imagine these relationships schematically in Figure 15. In reality, the pilot only has imprecise knowledge of the relationship between speed, land out probability, and risk. In order to optimize speed while respecting the strategic risk baseline, the pilot must adopt an iterative approach. For a pilot in a risk minimizing frame this means "tuning" to increase speed without taking too much risk. A pilot in a racing frame will tune to decrease risk in ways that have little effect on efficiency.

This is likely to lead to behaviors where the pilot chooses a frame (perhaps subconsciously) which prioritizes whether losing speed or minimizing risk is the dominant concern and subsequently adjusts the output based on the secondary concern. The pilot chooses a frame based on the *perceived* relative sensitivity of speed and probability of landing out to the risk tolerance. This explains why pilots rapidly "shift gears" when experiencing a change in weather or an unexpectedly high risk situation – the pilot is confronted with the fact that she does not know the shape of the curves depicted in Figure 15 or her true position on them. Shifting gears provides the opportunity to gather information and tune risk tolerance while avoiding a high risk of landing out. Similarly, in slowly deteriorating or improving conditions a pilot may not change gears until having to "dig out" or when a late starter joins them in a thermal.



(a) In an environment which lightly penalizes risk, the pilot can initially be much more aggressive. We expect that this permits an initial behavior closer to the optimal speed while not exposing the pilot to too great a risk of landing out.

(b) In an environment which progressively and heavily penalizes risk taking, it is likely better to begin in a risk minimization frame and slowly tune the risk tolerance to increase speed.

Fig. 15 Two examples of the behavior that could occur when a reward behavior is introduced into the decision-making process. Depending on the relative shapes of the speed and failure curves, a racing or risk minimization frame might be chosen. In either case the pilot will tune their behavior toward the optimum from their starting frame. The pure risk minimization frame can be imagined as the left and racing as right side of the figure.

In this model, the two frames are still highly relevant, but they become a statement of what a pilot initially experiences as a loss. Whether the pilot is primarily concerned with losing efficiency or landing out anchors how he appraises his situation and is the primary driver of decision making. Subsequently, the pilot will tune the output to satisfy the secondary objective of maximizing speed or minimizing risk accordingly. When racing, slowing down is experienced as a loss but the pilot tunes his outputs based on the possible paths to increase the number of thermals available. For instance, if the pilot has two paths available that are nearly equally optimal in speed, but one path has more potential thermals, it is natural that even a pilot in a racing frame would sacrifice a little bit of speed for a path that meaningfully minimizes his risk exposure. On the other hand, when minimizing risk, anything that increases the likelihood of landing out is experienced as a loss. However, if a pilot has two paths available that are nearly equal in risk, but one path is faster, it is natural that the pilot would seriously consider taking a little bit more risk to meaningfully increase speed. The place that tuning holds in the decision-making process is depicted schematically in Figure 16.

Sometimes, pilots can be in completely different frames and their adjustments to their initial outputs can essentially converge on the same decision. Consider a scenario: two pilots are side-by-side and there is only one cloud ahead of them which has a 70 percent chance of working. One pilot is in the risk minimization frame; he wisely recognizes the high risk of landing out in this situation. However, since there is no chance of finding another thermal, he realizes that flying optimal MC speed does not meaningfully lower the likelihood of finding that thermal and speeds up accordingly. The other pilot is in a highly aggressive "racing" mode and is driving hard toward that one thermal, figuring that the reward of this particular climb justifies the risk. Both pilots are flying in the exact same manner, despite being in different frames.

However, sometimes the risk minimization and racing frames can lead to very different outputs, even when pilots are tuning their outputs to consider the effects of both risk and reward. To continue the proposed scenario, once the

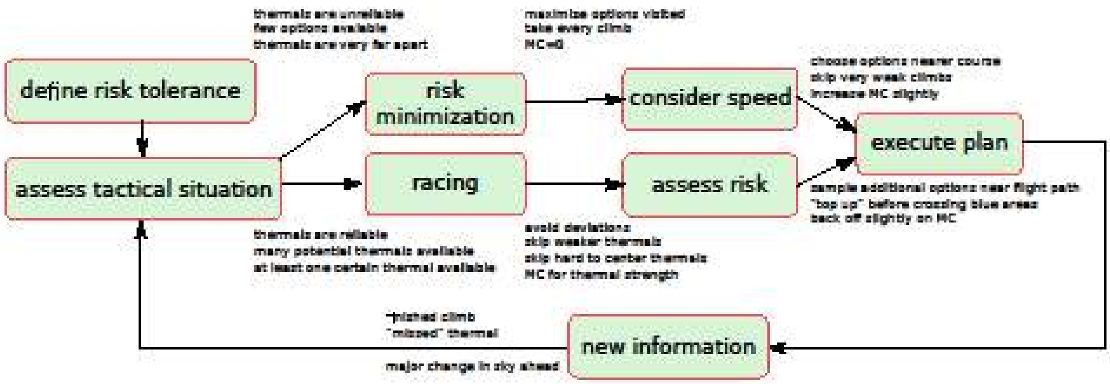


Fig. 16 Considering reward in decision making can be thought of as adding an additional step to the process described in Figure 8. "Tuning" is the process of invoking some elements of the secondary decision making frame to either increase efficiency (when in the risk minimization frame) or decrease risk (in the racing frame). The strength of the tuning effect will depend on the relative intensity of the loss and reward felt by the pilot.

pilots climb up to cloudbase, they must now consider how they will pursue their next glide. They see a blue hole ahead and have two options: accept a major deviation around it, or make a highly aggressive dash across the middle, with very few thermal options on the other side. The pilot in the "racing" frame charges across the blue hole whereas the pilot in the "risk minimization" frame chooses a very different course which increases the number of clouds available in order to limit his risk exposure.

In such a case, the "racing" pilot may tune her output by flying somewhat slower across the blue hole to arrive at the other side at a greater altitude and thus able to reach more potential thermals. The "risk minimization" pilot may tune his output by accepting a path with slightly fewer clouds and flying closer to the MacCready speed than in the "pure" version of his frame. However, the initial outputs from the racing and risk minimization frames could be so divergent that it may be impossible for the pilots to converge on the same decision. When confronted with a tactical situation where shifting from racing to risk minimization yields a very different output, choosing the right frame becomes especially consequential as choosing incorrectly can be extremely costly.

VII. Conclusion

We explored the decision-making process to manage sporting risk in thermal soaring. We began by determining the level of risk which is appropriate for success in contest flying. Because landing out in most competitions is extremely costly, pilots must avoid landing out even once in order to be competitive. We show that pilots generally cannot accept a risk tolerance greater 0.001 and expect to succeed in the long run. The probability of landing out in a contest is extremely sensitive to risk: a risk tolerance of 0.01 greatly increases the likelihood of landing out when assessed over several days. However, a pilot may be justified in increasing risk tolerance toward the end of the competition. The sensitivity of landing out to risk motivates the definition of what we call the "strategic baseline" – a level of risk which provides an acceptable probability of landing out.

Next we consider how this translates into the cockpit. Starting from the strategic risk permissible in a contest, we define tactical risk: the risk one can accept on a given glide. We use a coin toss model to assess how thermal reliability and the number of options to sample affect a pilot's risk exposure. We find that when thermal reliability is low, it is almost impossible to have enough options to maintain a manageable risk threshold. On the other hand, when reliability is high, the pilot can maintain very few thermal options and have very low risk exposure.

The sensitivity of tactical risk to the number and reliability of thermal options motivates the existence of two modes: racing and risk minimization. These decision-making frames are rooted in cognitive science: they represent an expression of what a pilot experiences as a loss in a given situation. We assert that "gear shifting" often discussed in soaring represents a transition from one frame to the other.

By using Monte Carlo simulations we are able to demonstrate that gear shifting can be used to significantly reduce the risk a pilot is exposed to if the pilot shifts frames when their risk tolerance is violated. We note that shifting gears carries an efficiency penalty as it requires greater deviations and slower speeds to maximize the number of options which can be sampled.

The steps outlined in this paper and illustrated in Figure 16 constitute a cognitive model for managing risk in thermal soaring. Assessing the level of risk, choosing a decision-making frame, tuning the dominant frame, and looking for new information while carrying out a flight plan forms a loop similar to the famous "OODA" loop for decision making[18]. While individual pilots may use different heuristics as they progress through this loop, the structure provides a systematic approach to evaluating and managing risk in thermal soaring. From the results of this investigation, the authors recommend several heuristics that can be applied by pilots in the cockpit to improve thermal soaring performance:

- The risk of landing out in a competition is extremely sensitive to the risk taken on each glide. The acceptable risk of landing out on each glide must be very small to complete a competition successfully.
- If more than half of the clouds are working, a pilot can become more selective about thermal choices. If fewer than half of the clouds work, conservatism is required to avoid landing out.
- Improvements in thermal "hit" probability can dramatically improve speed and reduce risk.
- Having strong confidence in at least one lift source ahead greatly diminishes risk exposure on the current glide.
- When assessing a tactical situation, ask yourself "should I be more concerned with speed or landing out."
- In reliable conditions, a racing frame can be maintained with relatively few options. A low risk tolerance costs little in speed while reducing the risk of landing out.
- In unreliable conditions, a low risk tolerance reduces speed more than it reduces the risk of landing out. Shifting to risk minimization early can significantly reduce the risk of landing out, permitting a higher risk tolerance.
- Consider an immediate shift to risk minimization when a good "line" through the cloud field ahead is not clear.

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- *Schweizer 2-33 two-place glider for rent*

Lunch options at airport

Cookout/Social Friday night

Cookout or local restaurants for dinner on Saturday night

Informal Soaring Seminar on Saturday Morning
Starting at 9:30 AM

Tell us you′re coming & let us know if you′re bringing a glider!!!
If you can′t bring a ship, just come and have fun.

Motels: Search maps.google.com for ′Motels East Wichita, KS′
start along North Greenwich Rd, Webb Rd or Rock Rd. down to US 54

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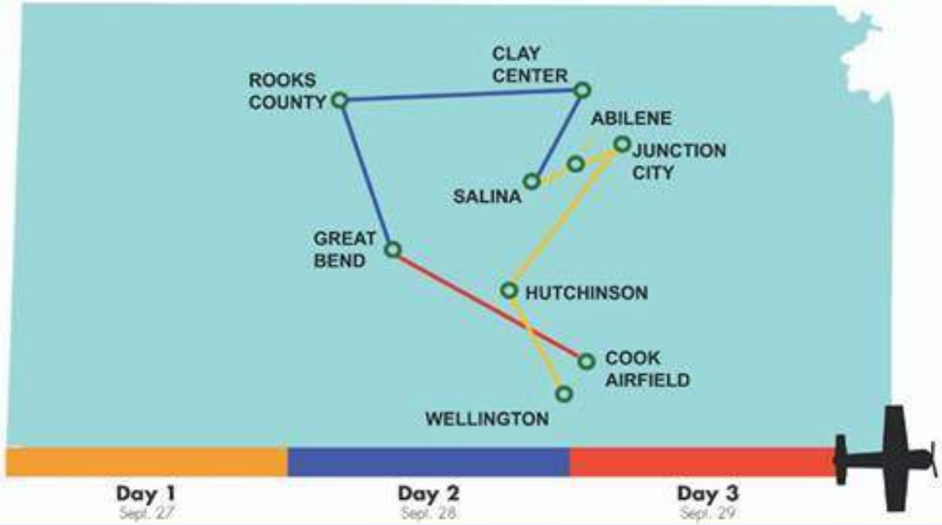

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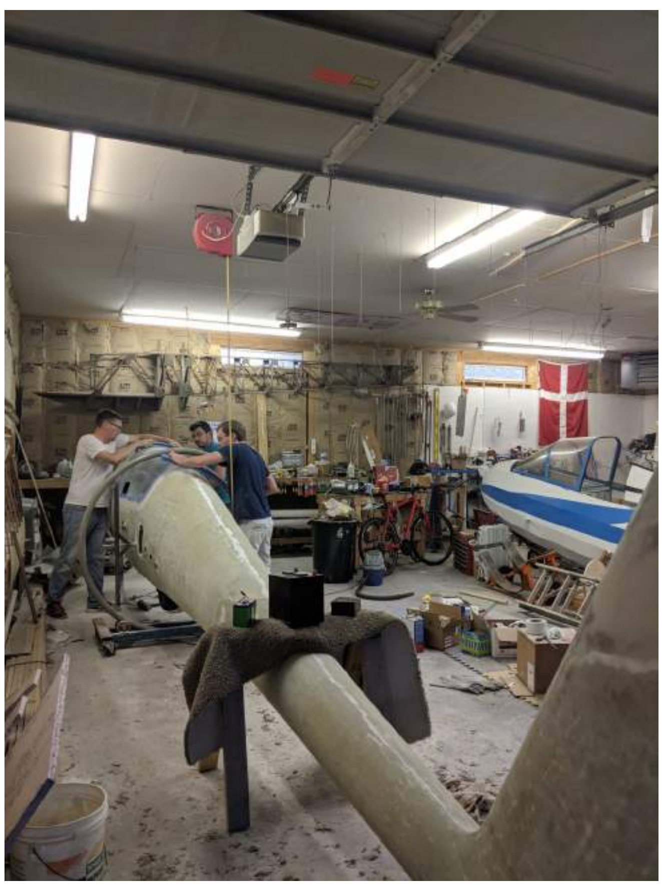
Matt Gonitzke is making good progress on his SH-1 trailer. Will be finished soon!

KC Alexander is making great progress on his PIK!

Grob Work

Rob Rippy and **Tony** work on a patch on the nose

Bob Hinson works on fairing in the gear doors



Tony, **Kirk Bittner**, and **Wilder Parks** fill in around the canopies

RULES FOR KSA FLYING AWARDS, 2018

Unless otherwise noted, the following applies to all awards:

For definition of bold terms, refer to the FAI Sporting Code Section 3-Gliding.

Awards are to be made for SOARING PERFORMANCES with a START POINT in the state of Kansas.

On distance and speed flights, the maximum LOSS OF HEIGHT allowed is 1000 meters (3281 feet)

For sailplanes without a SSA handicap, a handicap will be established by the KSA Board of Directors.

If disposable ballast is on board at takeoff, any handicap will be further multiplied by .92.

Flight documentation shall be submitted in .igc format

Task Declarations may be electronic, written, or verbal

TURNPOINTS will be attained by entering an OBSERVATION ZONE

Wooden Wings

The Wooden Wings Trophy is awarded for the longest distance SOARING PERFORMANCE in a wooden winged sailplane. The task may be FREE DISTANCE or 3 TURN POINT DISTANCE.

If the COURSE is abandoned before all TURNPOINTS are achieved, the flight will be scored as the distance for the achieved TURNPOINTS, plus the distance to the next declared TURNPOINT, minus the distance from the FIX establishing a landing or starting of a MoP to the next attempted TURNPOINT, but not less than the distance to the last achieved TURNPOINT.

Mamie Cup

The Mamie Cup is awarded for the longest distance SOARING PERFORMANCE of the year. The task may be FREE DISTANCE or 3 TURN POINT DISTANCE.

If the COURSE is abandoned before all TURNPOINTS are achieved, the flight will be scored as the distance for the achieved TURNPOINTS, plus the distance to the next declared TURNPOINT, minus the distance from the FIX establishing a landing or starting of a MoP to the next attempted TURNPOINT, but not less than the distance to the last achieved TURNPOINT.

KSA Flying Horse (Silver)

The KSA Flying Horse Trophy is awarded for the highest speed achieved around a CLOSED COURSE with a maximum of two declared TURNPOINTS and OFFICIAL DISTANCE of at least 100km and less than 200km.

Dennis Brown Memorial

The Dennis Brown Memorial Trophy is awarded for the highest speed achieved around a CLOSED COURSE with a maximum of two declared TURNPOINTS and OFFICIAL DISTANCE of at least 200km and less than 300km.

KSA Flying Horse (Gold)

The KSA Flying Horse Trophy is awarded for the highest speed achieved around a CLOSED COURSE with a maximum of two declared TURNPOINTS and OFFICIAL DISTANCE of at least 300km.

Curt McNay Pilot of the Year

The Curt McNay Pilot of the Year Trophy is awarded for the best combined score in four tasks - DURATION (6 hours maximum), GAIN OF HEIGHT, Handicapped Distance, and Handicapped Speed. Each task will be scored from a different SOARING PERFORMANCE.

The Distance task may be FREE DISTANCE or 3 TURN POINT DISTANCE.

If the COURSE is abandoned before all TURNPOINTS are achieved, the flight will be scored as the distance for the achieved TURNPOINTS, plus the distance to the next declared TURNPOINT, minus the distance from the FIX establishing a landing or starting of a MoP to the next attempted TURNPOINT, but not less than the distance to the last achieved TURNPOINT.

The speed task must be a CLOSED COURSE with an OFFICIAL DISTANCE of at least 100 KM. However, a 3 TURN POINT DISTANCE of at least 200 KM may be used if you are flying a sailplane with a handicap of 1.36 or greater. In this case, a wind correction factor of 15 MPH will be subtracted from the achieved speed prior to scoring.

1000 points will be awarded the best performance in each task. Each contestant's performance will be ratioed according to the best performance in the task being evaluated. The sum of each contestant's scores will be compared, the highest being the winner.

Charles Henning Award

The intent of this trophy is to encourage more people to fly cross country.

1) The cross country task will be a CLOSED COURSE with any number of TURNPOINTS.

2) Handicapped Speed will be determined by the DURATION or 2 Hours, whichever is greater.

3) There is no limit on start or finish altitude.

5) TURNPOINTS may be any TURNPOINT published in the KSA Turnpoint File or a public use airport marked on a Sectional Chart.

6) The winner will be determined by averaging the two best tasks of the year for each pilot. The averaging will be accomplished by adding the two speeds and dividing by 2.

Lead C

Awarded to the pilot or soaring supporter who makes the most noteworthy non-achievement during the calendar year.

Praying Mantis

The Praying Mantis is awarded to the pilot who makes the most significant advance in his or her soaring ability during the calendar year. To be eligible for this award, the pilot must not yet have his or her Silver Badge at the beginning of the calendar year. The Praying Mantis selection committee consists of the KSA President, WSA President, *Variometer* Editor, WSA Chief Instructor, and the SSA State Governor for Kansas.

Towing Operations

The Towing Operations trophy is awarded to the person making the most significant contribution to the operation of the KSA Towplanes for the year.

Maintenance Trophy

The Maintenance Trophy is awarded to the person making the greatest contribution via maintaining equipment related to soaring flight during the year.

KSA Duty Schedule 2018

Saturday September 8	Jerry Boone 620-474-4177	Steve Damon 620-386-0770	
Sunday, September 9		Kevin Ganoung 785-536-4540	Steve Damon 620-386-0770
Saturday, September 15	Paul Sodamann 785-456-5654	Dave Wilkus 316-706-9261	
Sunday, September 16	Brian Bird 620-664-7844		
Saturday, September 22	Michael Groszek 206-412-985		
Sunday, September 23	Bob Hinson 316-84-5561	Kevin Ganoung 785-536-4540	
Saturday, September 29		Matt Gonitzke 815-980-6944	
Sunday, September 30	Jerry Boone 620-474-4177	David Kennedy 316-841-2912	Steve Leonard 316-249-7248
Saturday, October 6	Bob Holliday 316-685-4545	David Wilkus 316-706-9261	Derald Wright 316-706-8379
Sunday, October 7	Mike Logback 620-755-1786	Sue Erlenwein 316-644-4586	Harry Clayton 316-644-9117
Saturday, October 13	Bob Holliday 316-685-4545	John Peters 620-755-3161	
Sunday, October 14	Bob Blanton 316-841-2921		Jerry Martin 620-960-5418
Saturday, October 20	Tony Condon 515-291-0089	Leah Condon 316-249-3535	
Sunday, October 21	Bob Blanton 316-841-2921	Keith Smith 785-643-6817	Jerry Martin 620-960-5418
Saturday, October 27	Mike Logback 620-755-1786	Matt Gonitzke 815-980-6944	
Sunday, October 28	Tony Condon 515-291-0089	Steve Leonard 316-249-7248	Jerry Martin 620-960-5418

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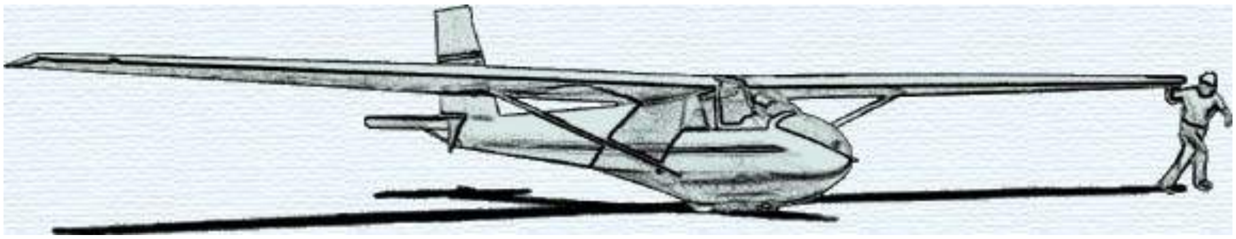

KSA Meeting

September 8th

Cookout at Sunflower

After Flying