Breakthroughs in Winch Technology
A Three Year Update

More Safety – More Performance

2003 "40 Seconds to Freedom"
A look back

- Winch launch is FUN and PRACTICAL
- Rising Fuel prices will make aero tow costly
- Forecast oil at ~$100 bbl - Avgas at $5 Gal
- Aero tows approaching $100
- Winch launches cost ~$2 pilots will pay $10
- Winches can deliver high launches (3200' agl)
- 4th generation winches under development
- Diesel, Automatic controls, Lightweight cable

2008 - 'Reality Check'

2005 predictions

- 'Maniacs' predict $100 oil
- Aero tows average $50
- Winch launch - $2
- UHMWPE rope $0.35/Ft.
- Height Record: 3100' AGL'
- Est. 100 launches/Day
- It's FUN!

2008 Reality

- $100 oil, 'Maniacs' say $150
- Aero tows ave. $75
- Winch launch $3
- UHMWPE $0.35/Ft.
- Height record: 5400' AGL
- Record: 612 launches/day
- Safer and even more FUN!

2008 'Reality Check' *(cont)*

2005 Status

- Spectra being tested
- Airspeed telemetry under development
- Physics poorly understood
- Advanced winches in R&D

2008 Reality

- "Winch specific" Spectra
- Glider specific telemetry units for sale.
- Good dynamical models
- "Elegant" Hydrostatic and Electric Drive winches have been built & tested

2008 Reality Check (cont)
Tow Plane Financials Deteriorate

- Airport noise complaints intensify
- Pawnee engine overhauls approach $30,000
- 100LL AVGAS averages $5/gal - $9 by summer?
- 100LL AVGAS future seriously in doubt
  - Whole countries have been cut off
  - Only one TEL producer (India) supplies world - No TEL, no 100LL
  - The few 3rd world states still using TEL in MOGAS will phase it out shortly
- Almost all MOGAS contains ethanol thus unusable
- GOOD NEWS: Many small airports losing their 'power' traffic will make good winch sites

2008 Reality Check (cont)
Winch Issues Come Into Focus

- Training shortfall
  - Many US instructors unfamiliar with winches
- "Best Practices" need much work.
  - Each winch site has unique methods
  - Safety is paramount – standards needed
- Many gliders will need CG hooks added
  - (Roughly $1200 parts & labor)
- "Winch Friendly" Airfields must be found.

Safety: Not An Option

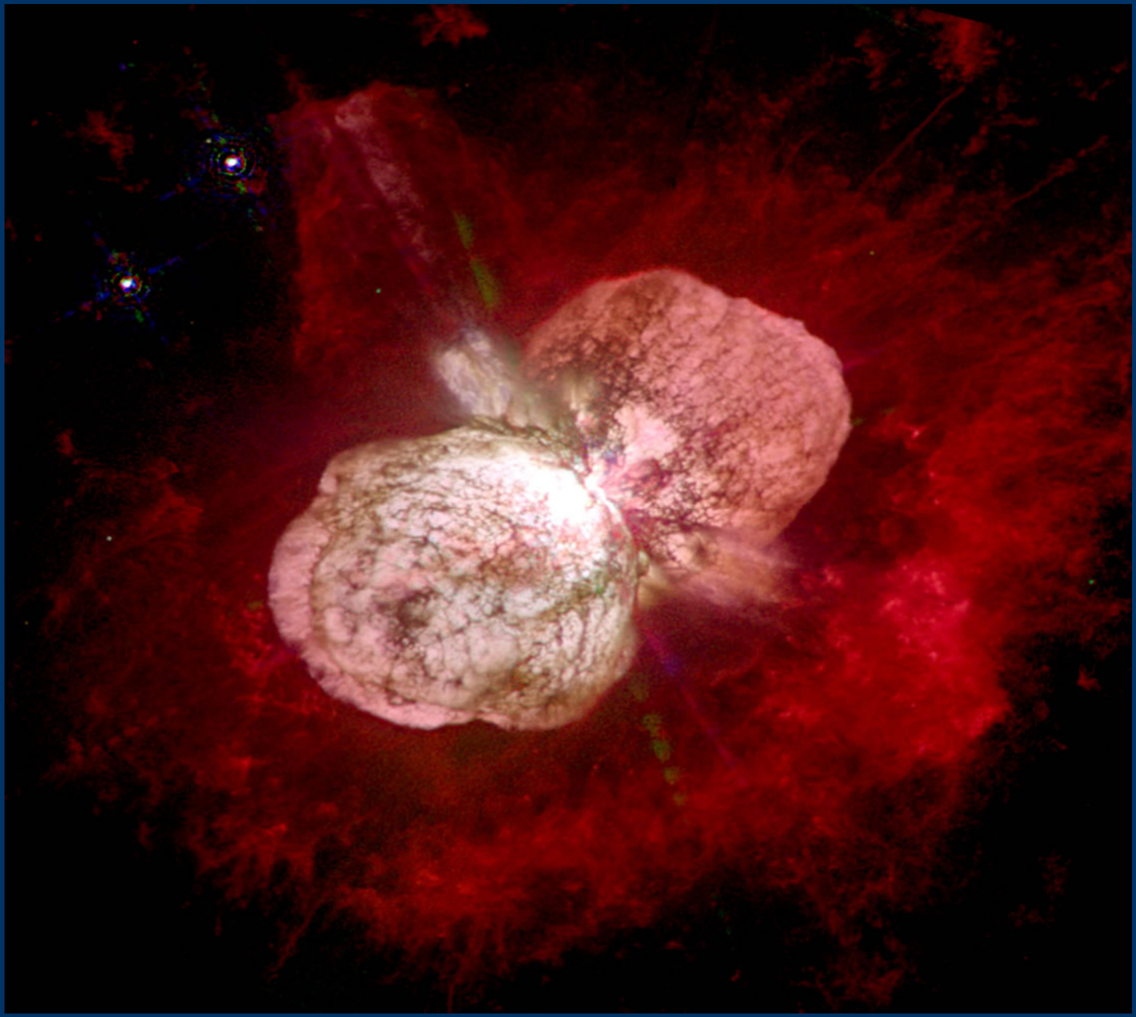
“Can it be made safe?” is the right question.

- The Dutch and Germans say it can.
  - Standardize “best practices”
  - Standardize training
  - Standardize winch safety design.
  - Field operations
  - Winch design
  - Winch operation
- Approach safety globally
- Don't leave any “weak links”

$100,000 for a winch? YIKES!!!
Some perspective

- In 1965 a Gehrlein winch cost about $11,000
  - 1 Drum, Piano wire, 'straight 6', 2 speed auto
  - Average 1965 automobile was $2,500
- In 2008 dollars that winch would cost:
  - $70,266.16 using the Consumer Price Index
  - $56,901.00 using the GDP deflator
  - $130,828.19 using the nominal GDP per capita
  - $201,837.99 using the relative share of GDP
- A 2008 4th gen winch offers a LOT more

"Mega-Numero-Phobia"



The fear of big numbers

Can ANYONE afford $100,000?
Some thoughts about how

1. A 5 Year, $100,000 loan at 6% = $1933 Payment
2. Assume cost at $3/launch & price at $15/launch
3. That nets an operating surplus of $12/launch
4. Assume 60 launches a day, 8 days a month
5. $12x60x8= $5760 per month cash flow
6. $3,827/Mo “Surplus” after debt service
   - Or: 'Break even' at 20 launches 8 days a month

The "Gotcha" is Utilization

- Your club may have to fly more often
  - But, now everyone can afford it.
  - Members even get an excuse to go flying:
  - *"Honey, I have to go flying to help the club pay for that new $100,000 winch."*
- You may have to recruit new club members
  - Cheap, fun launches make this easier
- Maybe the club is forced to buy more gliders
- ***ISN'T THIS WHAT IT'S ALL ABOUT?***

Youth Drives Utilization

Back to Winch Tech – What's New?
Avalanche of New Technologies

Solid mathematical models emerge – Understanding improves

'Rational' winch design based on physical laws

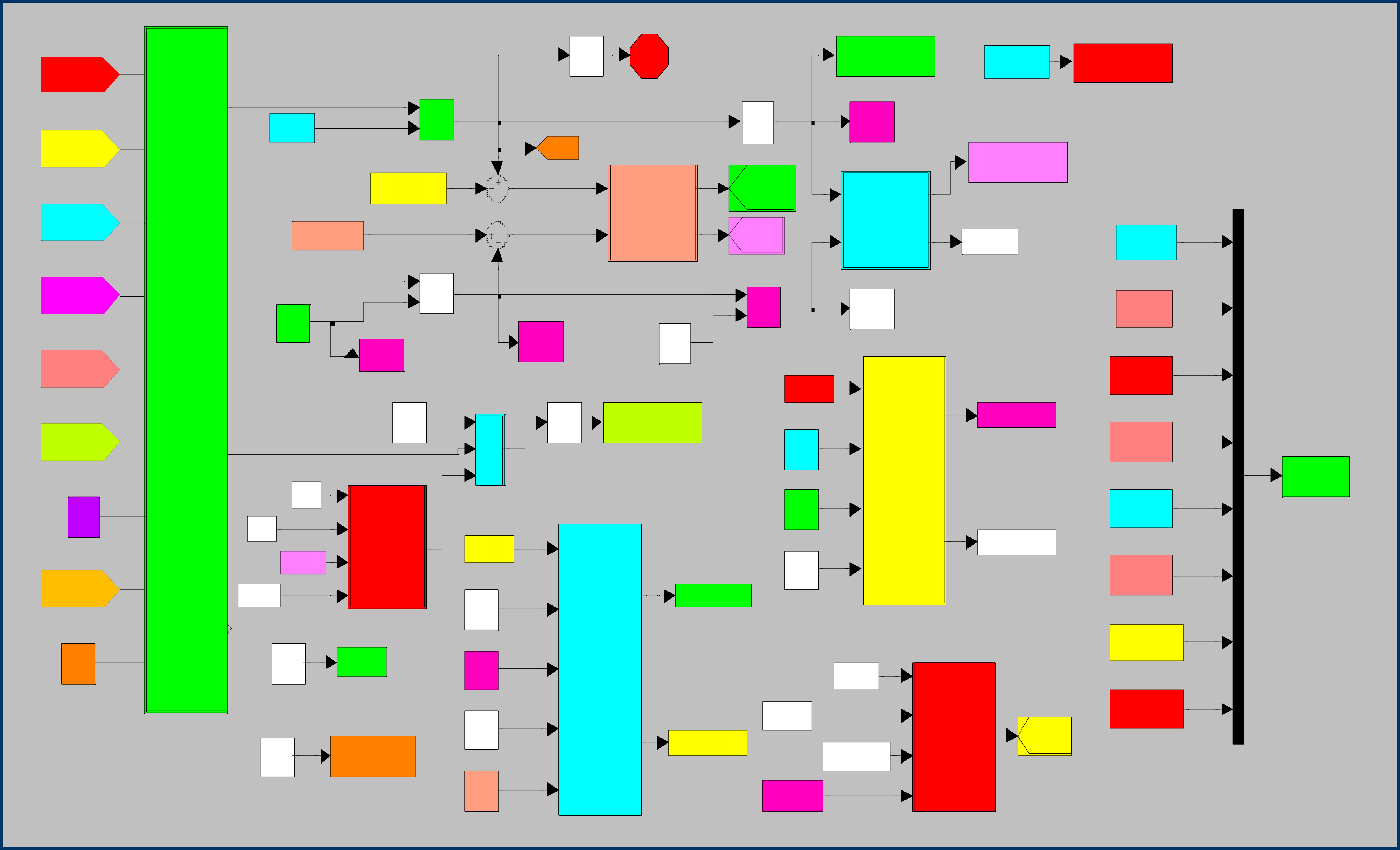
Computers provide highly accurate winch control/automation

Highly advanced, US-built winches come to market

What Does the Pilot Want?

- **Improved Pilot Experience**
  - **More consistent and predictable launches**
    - **Winch operator does not have to judge glider speed over half mile away**
    - **Reduced potential for pilot and operator to enter oscillatory behaviours**
  - **Natural airspeed control**
    - **Pull Back to Slow, Push Forward to Speed Up**
- **Improved Safety**
  - **Reduced weak link and rope failures**
  - **Superior windshear/downburst accommodation**
- **Higher Launches**
  - **Approaching 50% for experienced pilots in capable gliders in no wind**
  - **Over 50% with moderate headwinds – 2,000 feet on 4,000 feet run!!!**

Analysis and Computer Modelling
Enabling Technology



Better Understanding = Superior Solutions

- "Tension Control" emerges as best solution
  - Pilot In Command (PIC) exercises airspeed control
  - Robust turbulence/wind shear accommodation
  - Far greater safety than classic winches and methods
  - Far fewer rope and weak link failures
    - Sound rope and weak links won't fail
  - Higher launches

What is Tension Controlled Launching?

- Winch holds <u>Cable *Tension*</u> constant (or slowly decreasing) throughout the climb.
  - <u>Cable *Speed*</u> is whatever is required to hold tension level
- Pilot controls airspeed with normal pitch inputs
  - Pull Back to Slow, Push Forward to Speed Up
- Closed Loop Tension Control
  - Closes a servo loop around a cable tensiometer
  - “Cruise control for tension”

Enabling Technologies

- Lightweight UHMWPE 'rope'
  - Extremely low elasticity and weight
  - reduces oscillatory behaviours
  - Effectively no length limitations - launches to over 5,400 feet
  - Simplifies winch design
- Embedded processors
  - Allows electronic control
- Continuously Variable Transmissions (CVTs)

Hydrostatic/Electric CVTs

- Extremely flexible drive layout
- Easily computer controlled
  - Extreme ease of use reduces driver training
  - Extremely smooth operation
  - Vastly reduced “Hassle factor”
  - Smooth launches
- No retrieve brake needed
- Smaller engines or motors

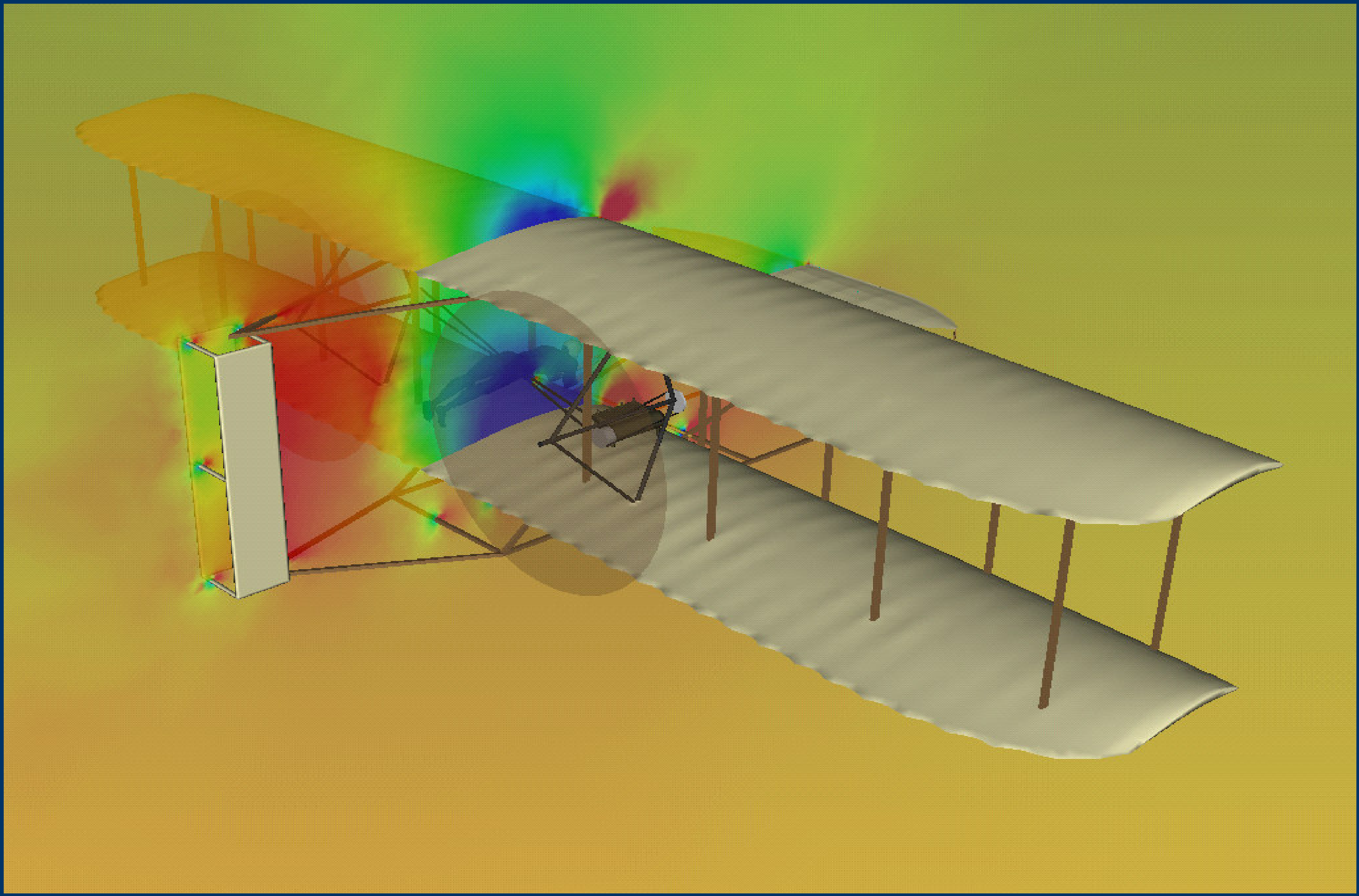
Computer Controlled Launch Automation

- Computer controlled cable speed, acceleration, tension
  - Launch Intensity selectable by PIC/operator
    - Gentle for beginners – aggressive for experienced pilots
  - Corrections applied for headwind component
  - Consistent, positive pilot experience

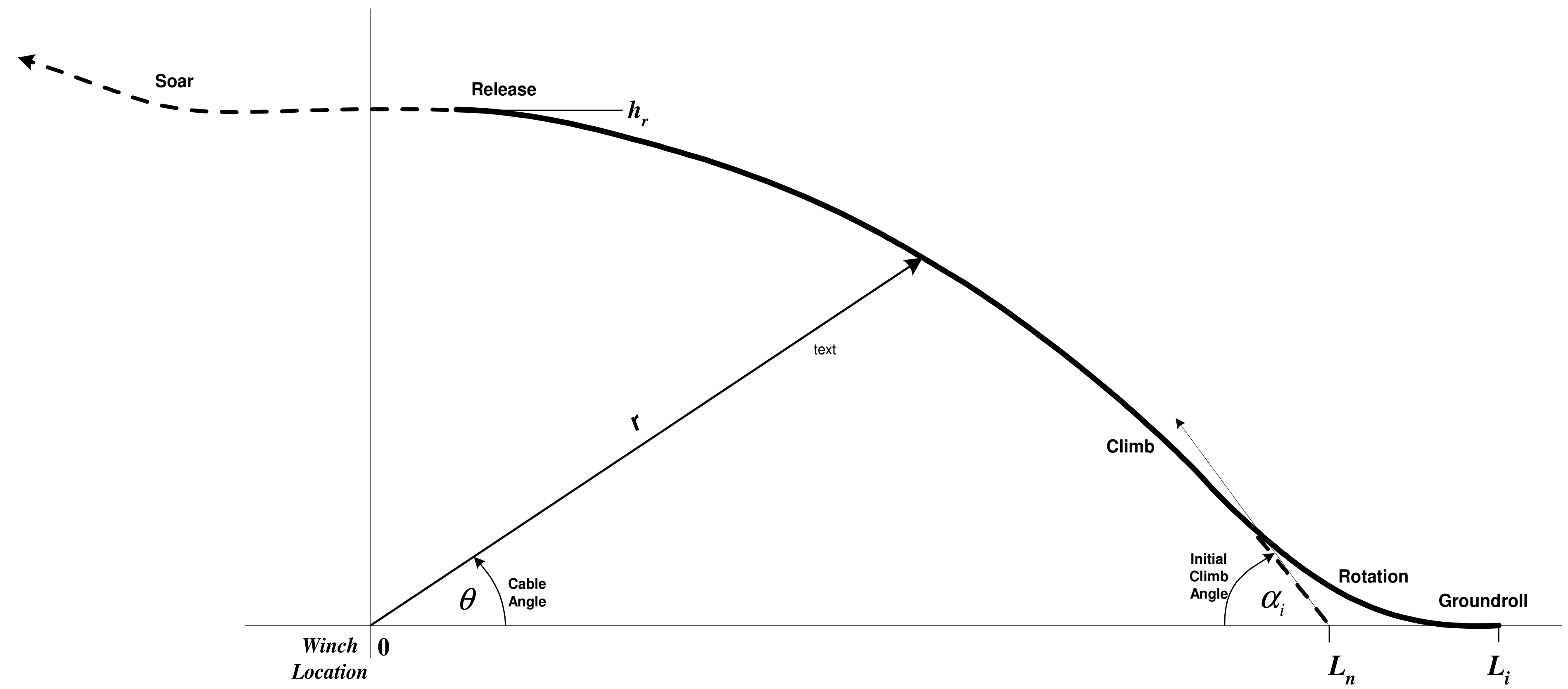
- Pilot focuses on airspeed, pitch, and pitch rate

- Winch operator stays in the loop
  - Can take control at any time if conditions require
  - Initiates take-up-slack
  - Controls glider release, and cable recovery/retrieve
  - Crucial to safe operation

Lets Look Under the Hood



Winch Launch Phases and Nomenclature



L_i = Initial Cable Length

L_n = Notional Cable Length: Length When Climb Trajectory is Back Projected to Ground

TF = Tension Factor (cable tension divided by glider flying weight)

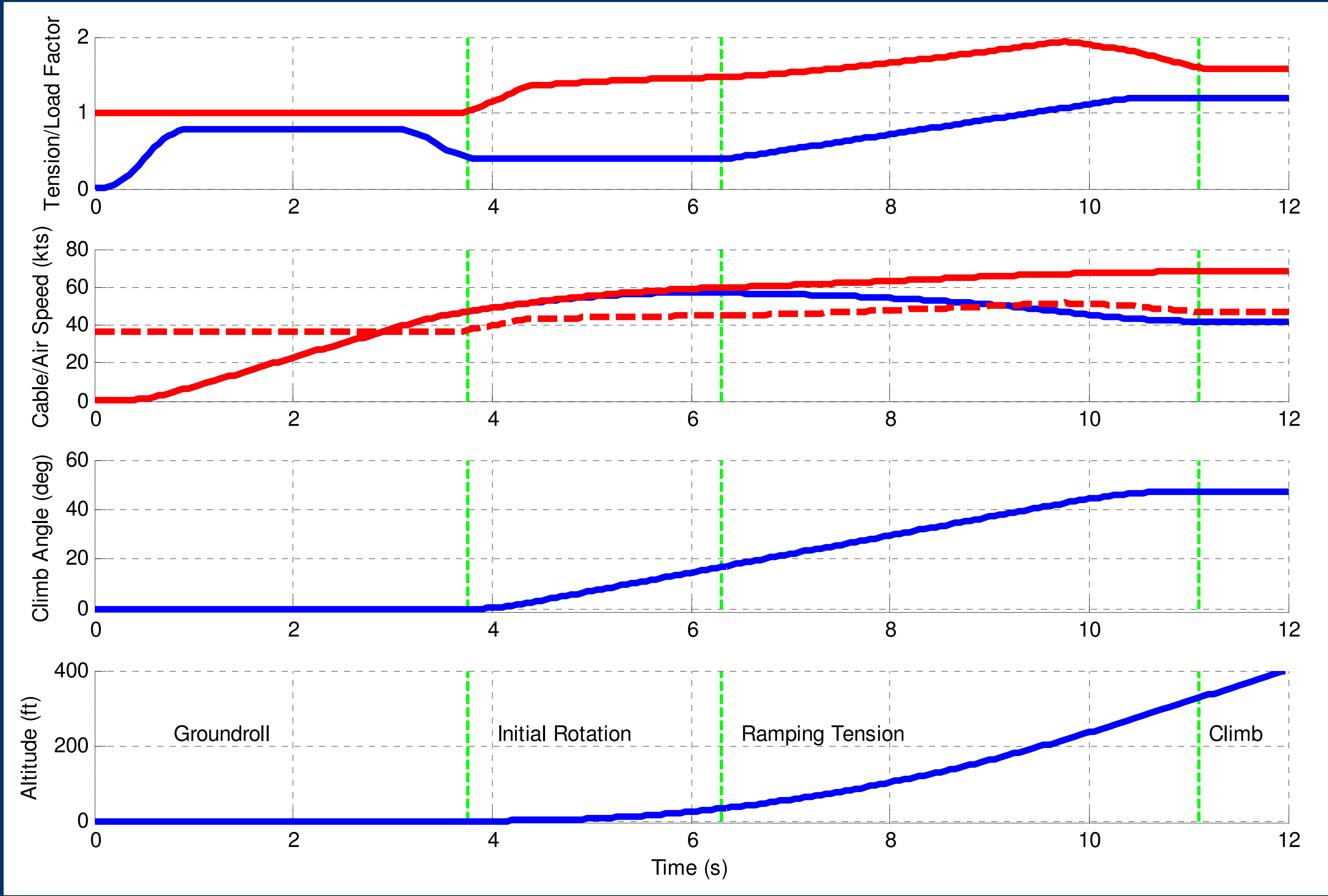
Example Trajectory - First 12 Seconds

Load/ Tension Factor

Air/Cable Speed

Climb Angle

Altitude

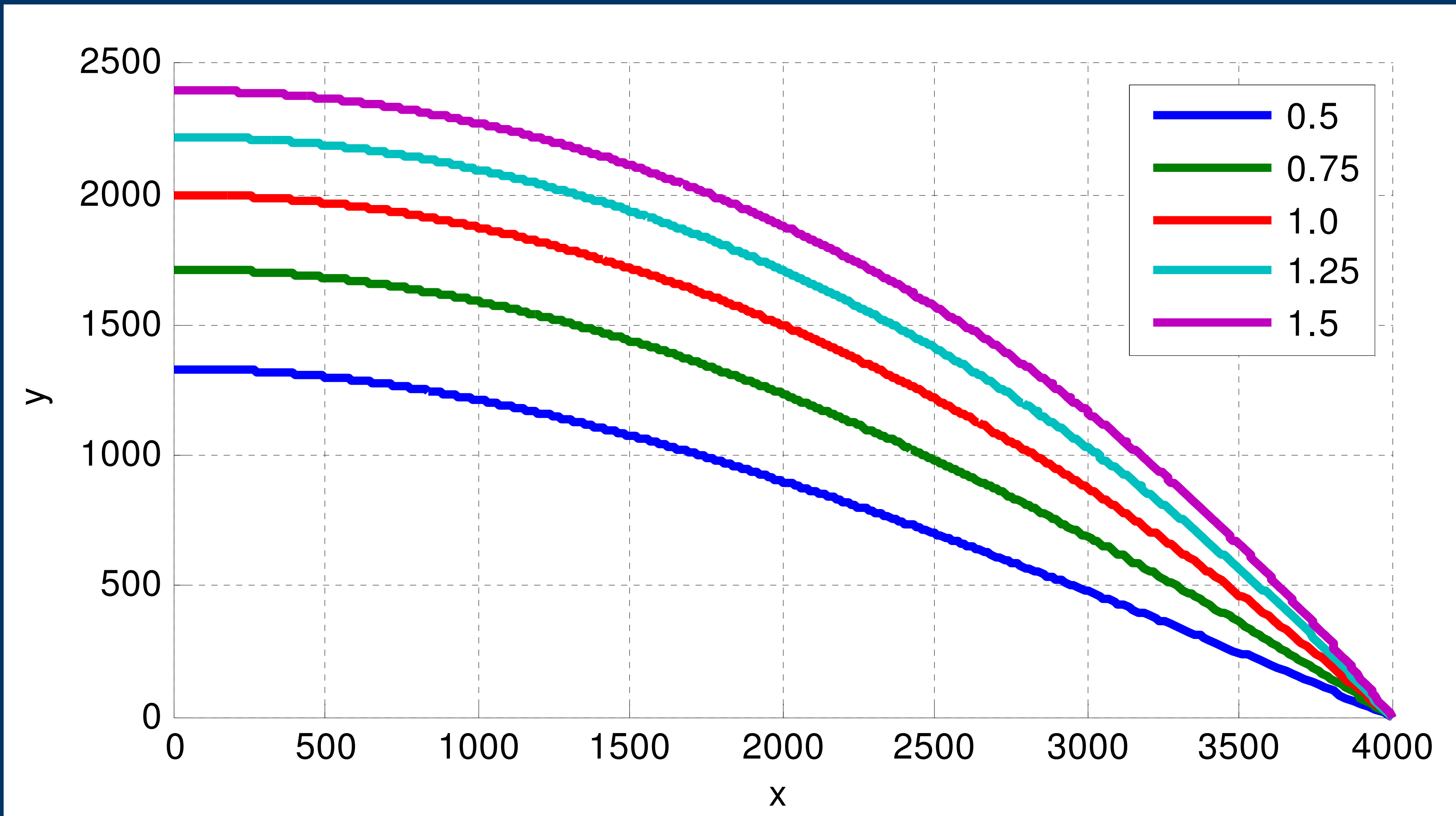


7.5 deg/sec

Time

Dynamical Analysis Results
Climb Trajectories vs. Tension

Ignoring drag and cable lifting losses, no wind

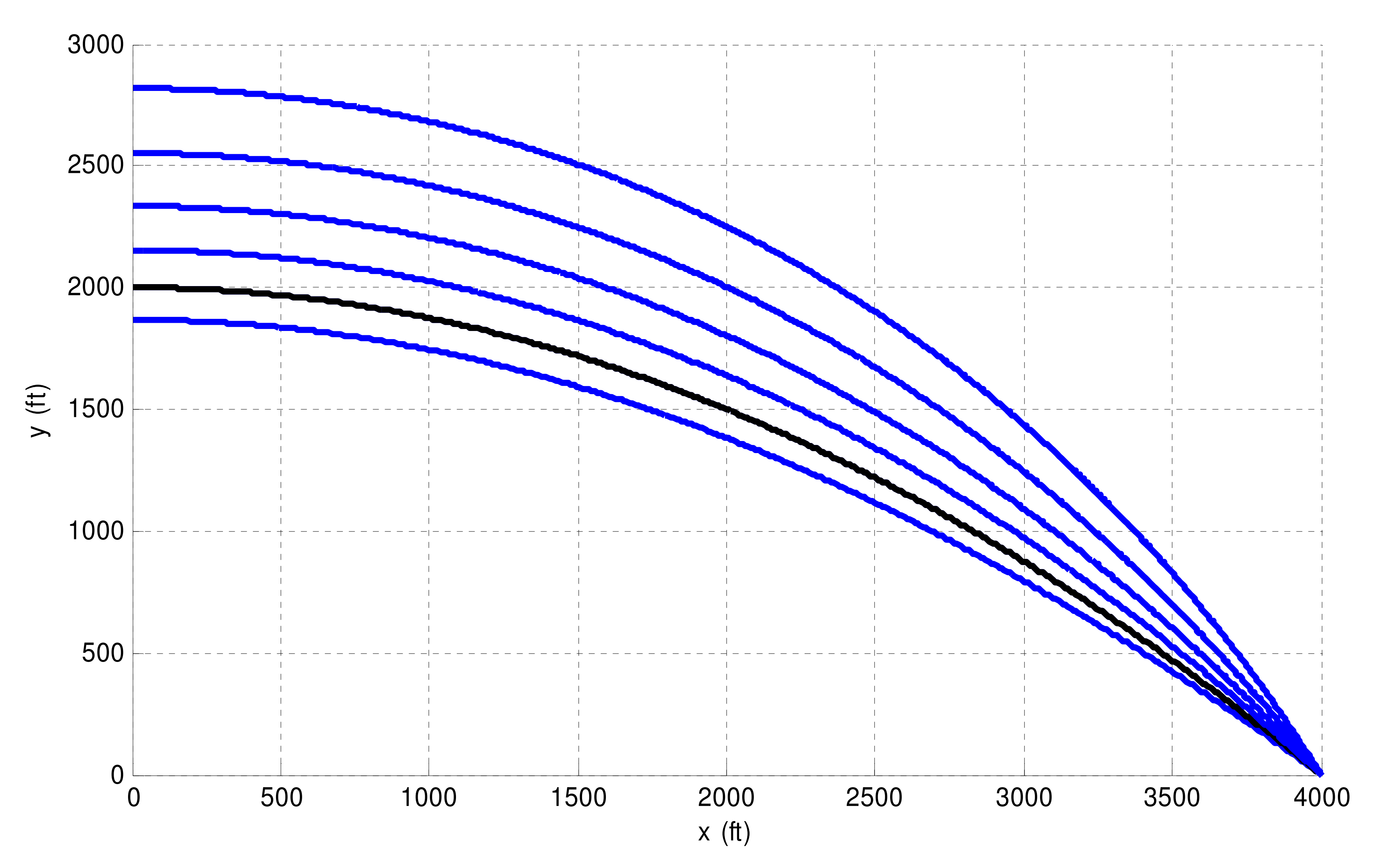


Idealized Lossless Climb Trajectories with Various Tension Factors

Real World Tension Limits

- Pilot preferences
- Weak link strength
- Winch Tension Control Accuracy
- Glider characteristics
  - Elevator authority insufficient to counter nose down moment
  - Airspeed required to generate required lift exceeds V_w
  - TF of ~ 1.5 probably near the upper limit for some gliders
  - Most gliders can use a TF of 1, many above 1.25
  - ASK-21 can use a TF of 2.0 if flown solo

Dynamical Analysis Results *(cont)*
Climb Trajectories with Wind



Idealized Lossless Climb Trajectories with -5, 0, 5, 10 15 kt Headwinds

Dynamical Analysis Results (cont)

12kt Positive Windshear

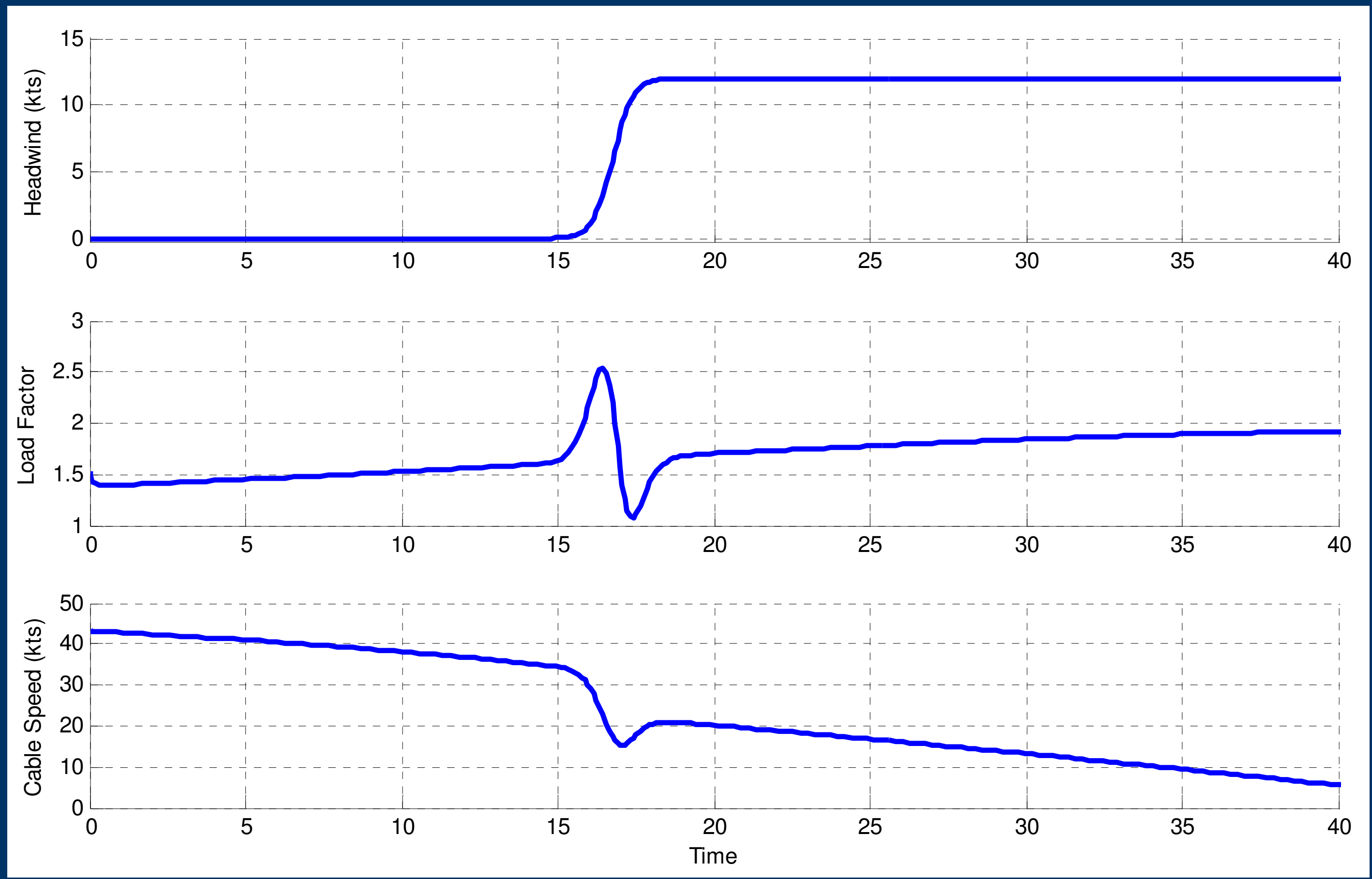
Winch holds tension constant throughout

Pilot focus is on controlling airspeed (AoA)

Headwind

Load Factor

Cable Speed



Time

Dynamical Analysis Results (cont)
50kt Downburst

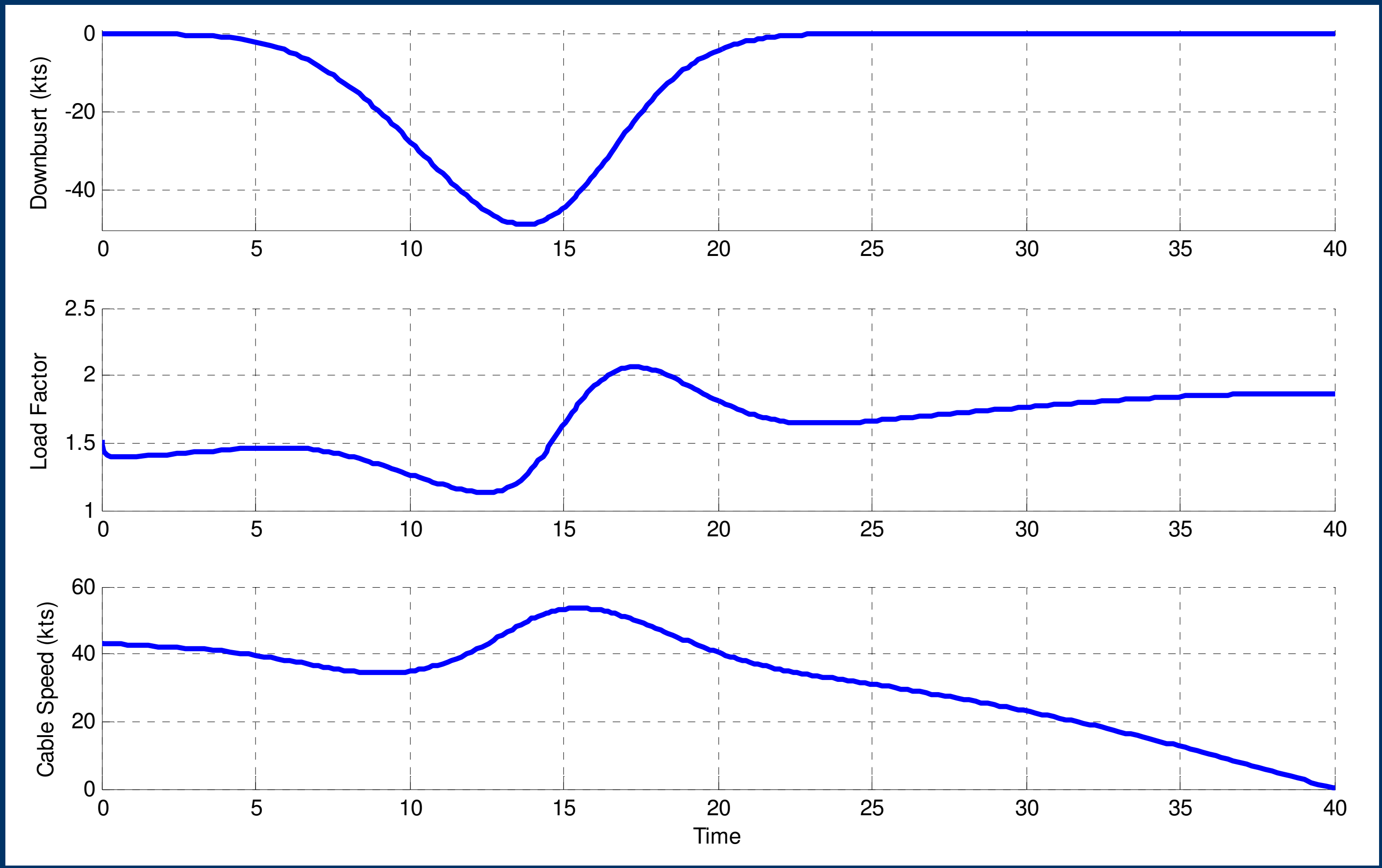
Winch maintains cable tension at constant value throughout event

Pilot continues to concentrate on airspeed control

Downburst Velocity

Load Factor

Cable Speed



Time

Understanding of Winch Dynamics + Optimal Control Methods = Major Benefits

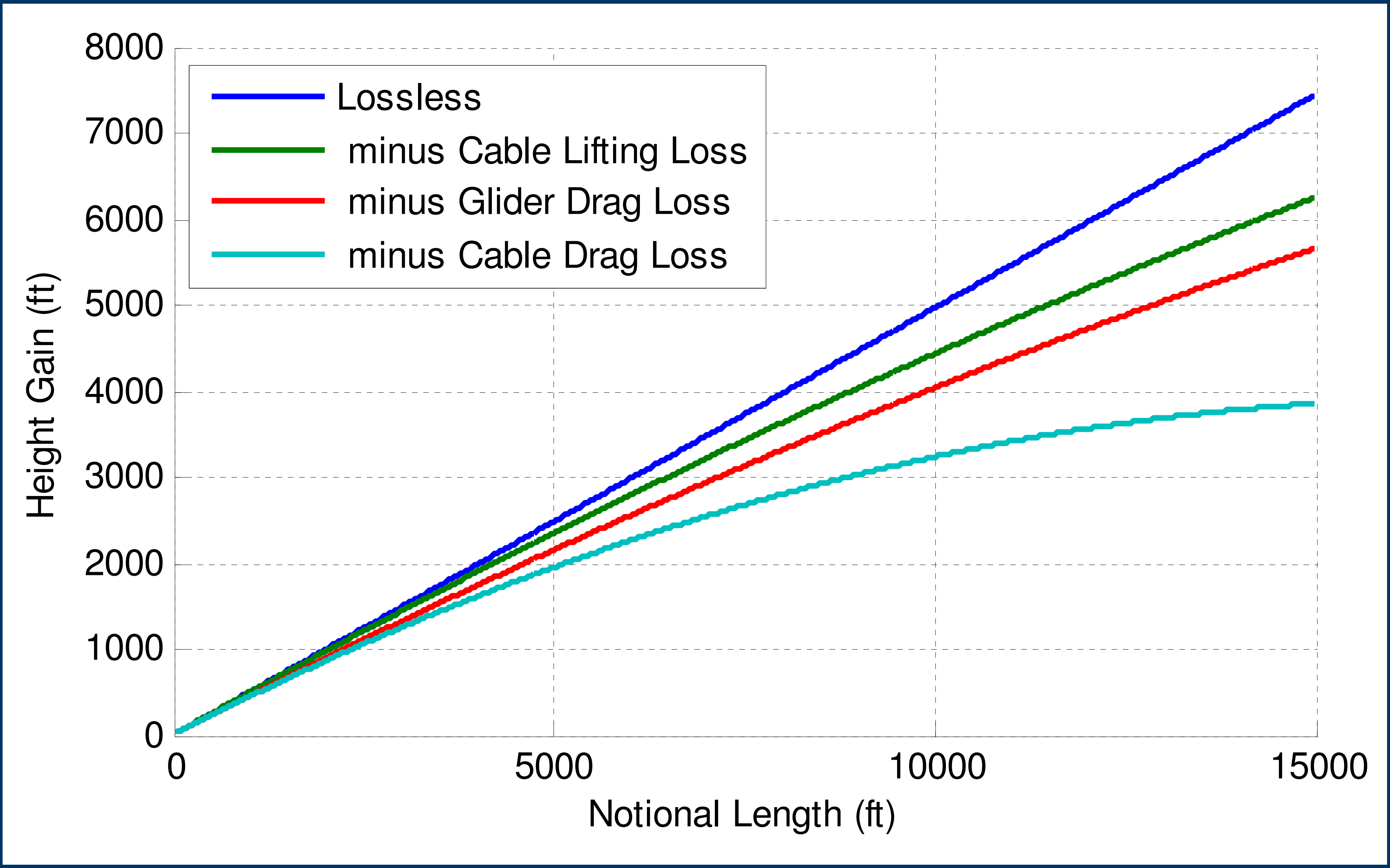
- Improved safety
  - Reduced weak link and rope failures
  - Superior windshear and downburst accommodation
  - Shifts airspeed control to pilot
- Superior Pilot Experience
  - Consistency and Predictability
- Higher launches (As percentage of rope length)
  - Near 50% for good pilots, capable gliders and no wind
  - Over 50% with moderate headwinds
    - >2,000 feet on 4,000 feet run!!!

Questions?

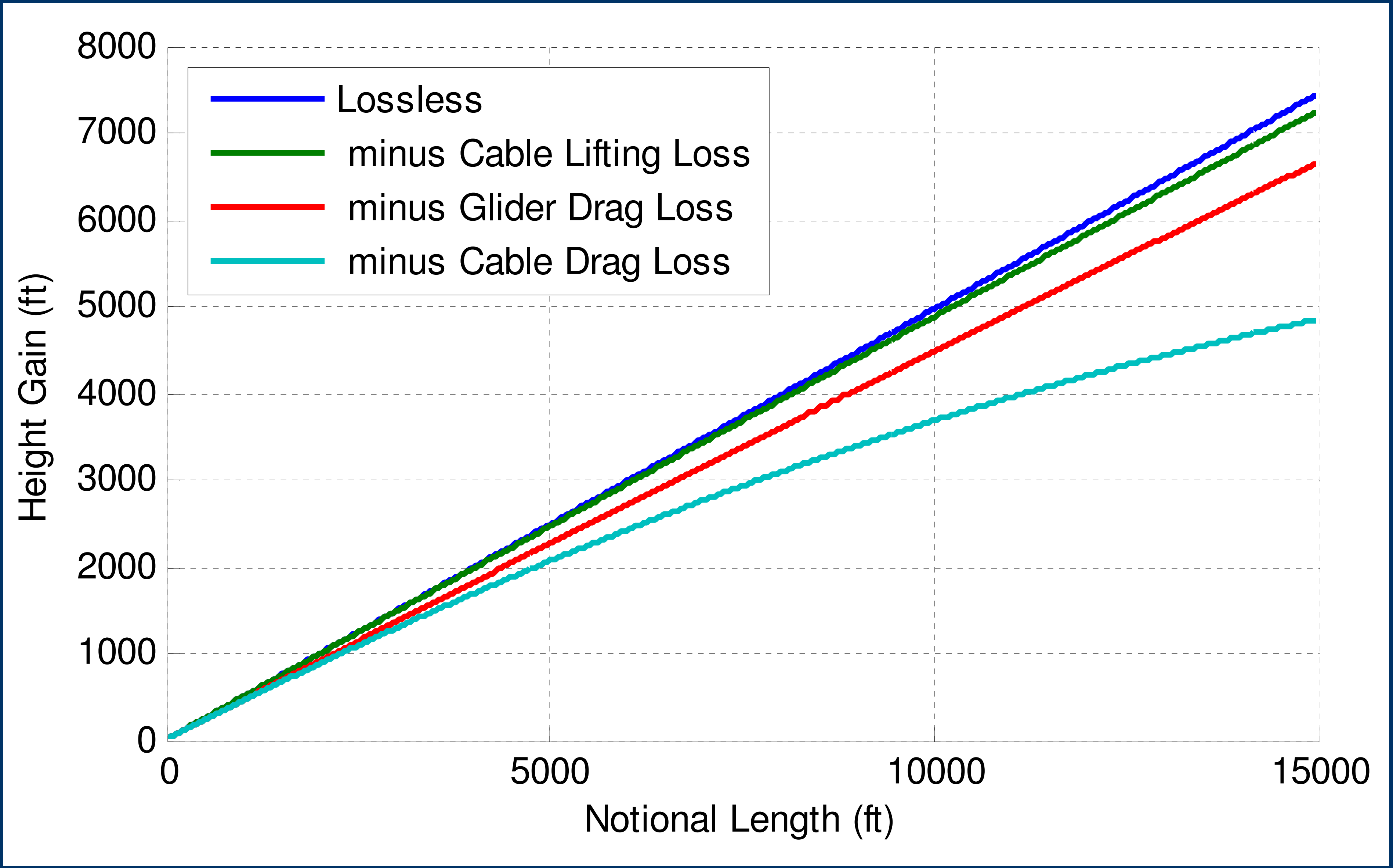
- For copies of slides
- Or more information
- Contact
  - Bill Daniels, bildan@comcast.net
  - George Moore, gsmbamoore@comcast.net

Backup Slides

Loss Contributors (Steel)



Loss Contributors (Spectra)



Dynamical Analysis Results *(cont)*

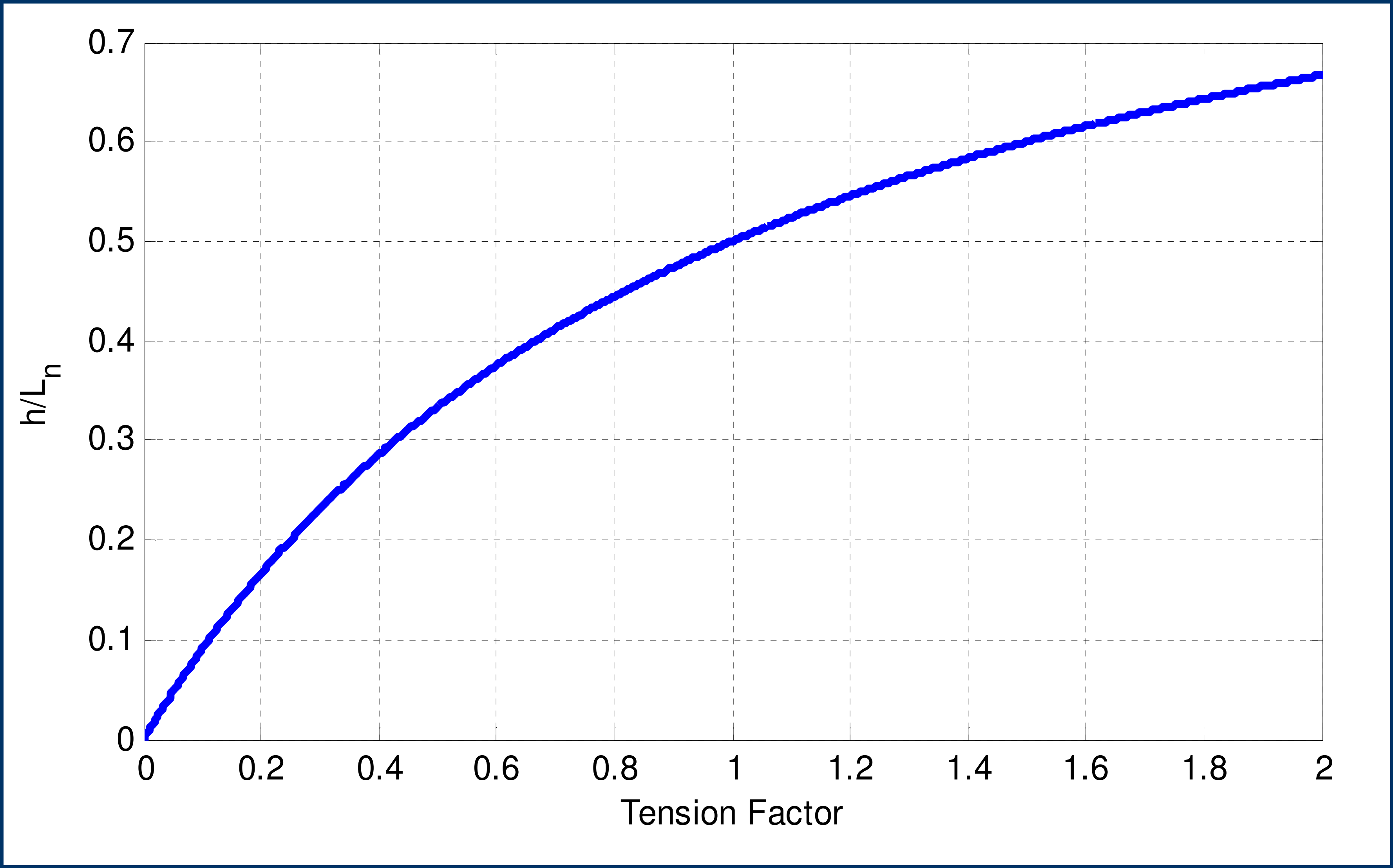
Equations have been developed for the critical parameters of launching under tension control. The most important, first expressed by Goulthorpe, is the height bound:

$$\frac{h_r}{L_n} = \frac{T}{1+T}$$

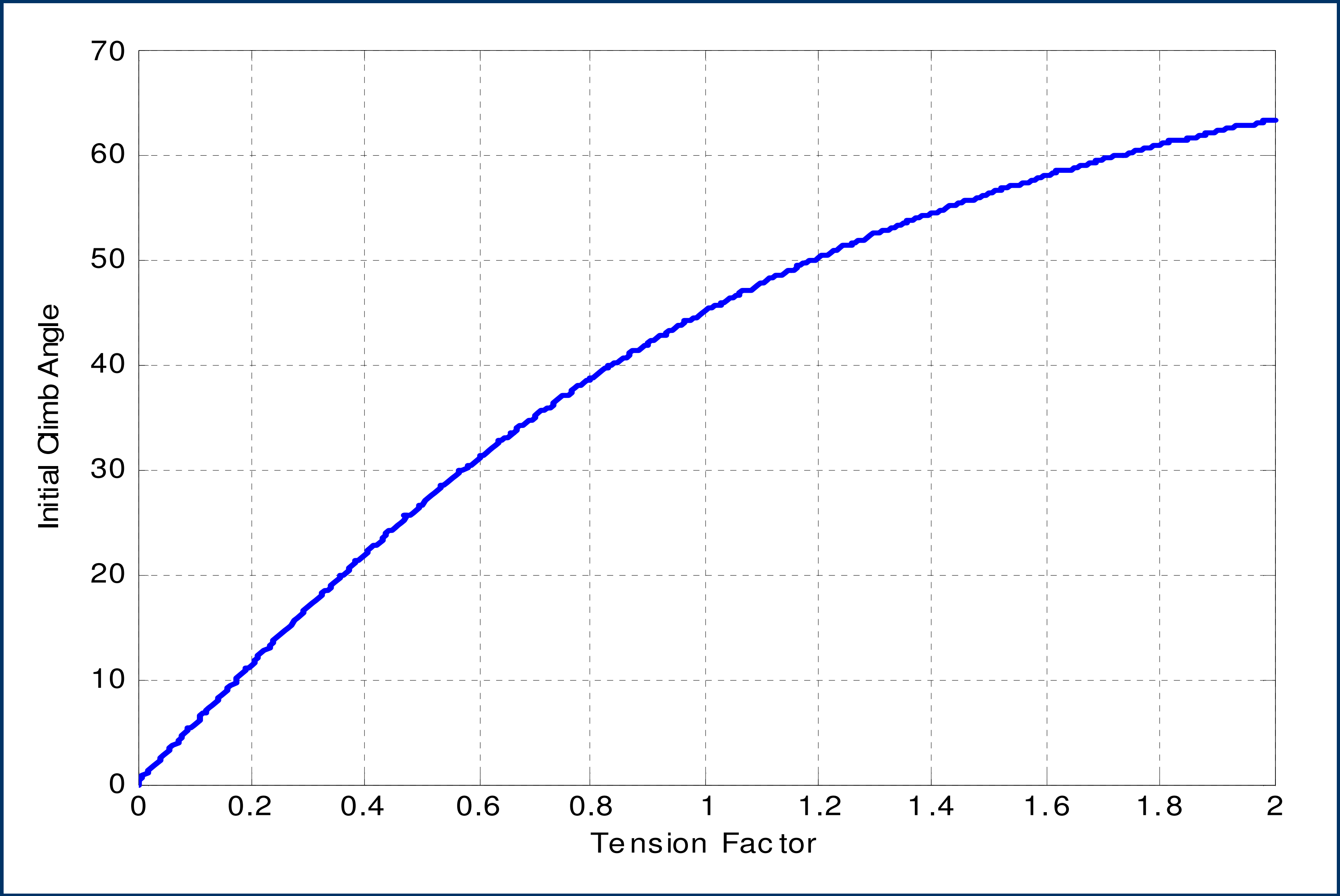
T	Height Bound (%)	Initial Climb Angle (deg)	Initial Lift Factor	Final Lift Factor
0.5	33	26	1.12	1.5
0.75	43	37	1.25	1.75
1.0	50	45	1.41	2.0
1.25	56	51	1.6	2.25
1.5	60	56	1.8	2.5
1.75	63	60	2.0	2.75

Bottom line: More tension = more height!!!!

Goulthorpe Height Bound



Initial Climb Angle (Lossless)



Effect of Airspeed (Lossless)