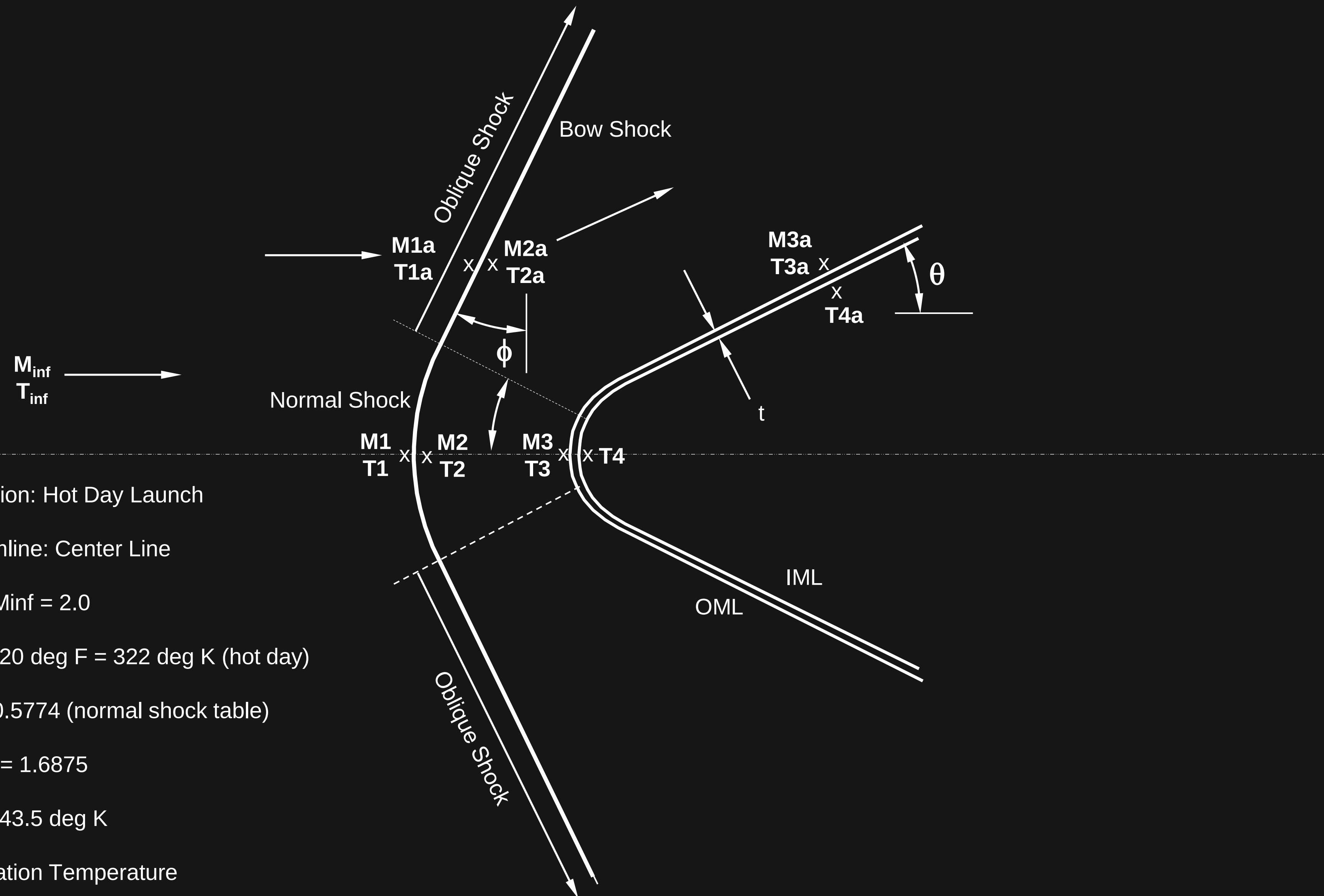
Stagnation Temperatures: Normal Shock



Condition: Hot Day Launch

Streamline: Center Line

M1 = Minf = 2.0

T1 = 120 deg F = 322 deg K (hot day)

M2 = 0.5774 (normal shock table)

T2/T1 = 1.6875

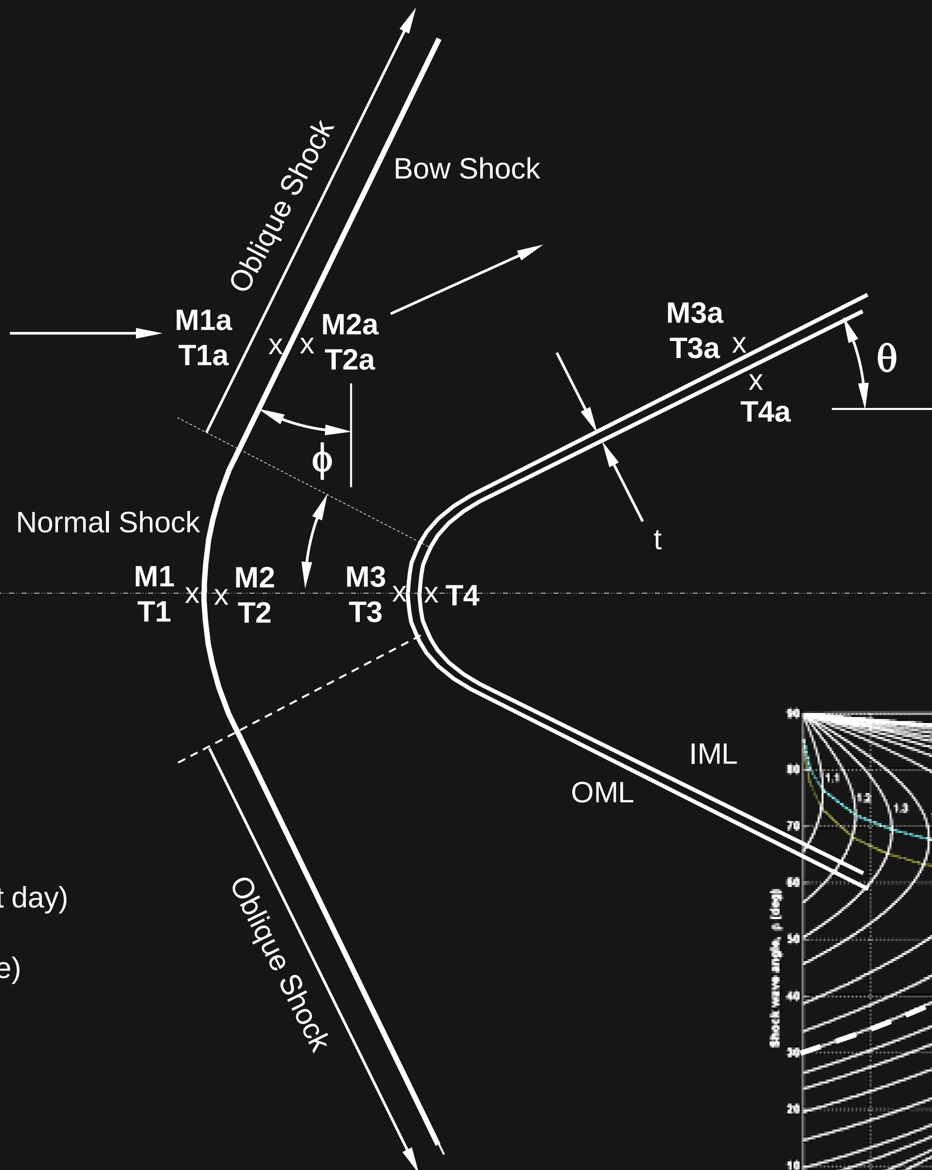
T2 = 543.5 deg K

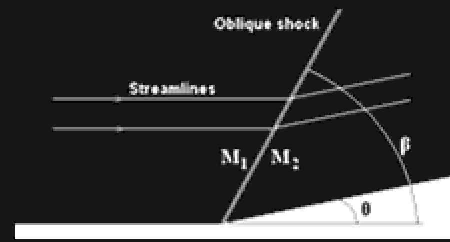
Stagnation Temperature

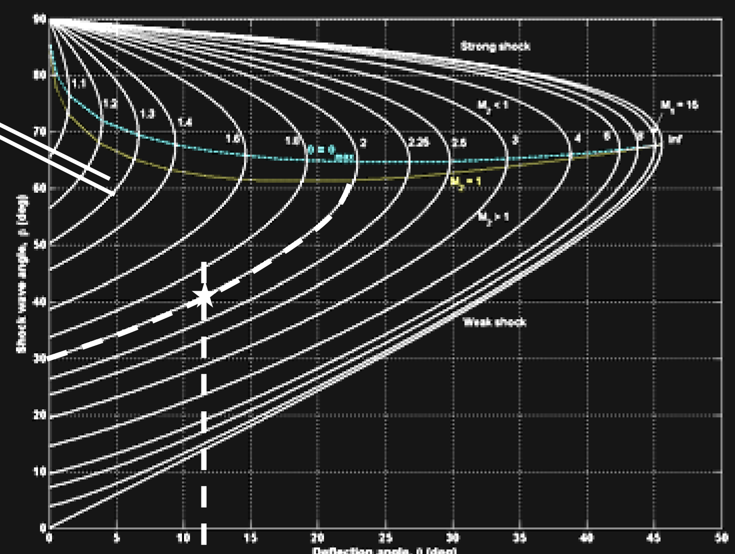
T3 = T0 = T2 (1 + ((gamma -1)/2) M2^2) = 579.7 deg K or 583.8 deg F

Compare to Recovery Temp P1 = 510 deg F => 510/584 = 12.6% loss (reasonable)

Stagnation Temperatures: Oblique Shock







Condition: Hot Day Launch

Streamline: Non-Center Line

M1 = Minf = 2.0

T1 = 120 deg F = 322 deg K (hot day)

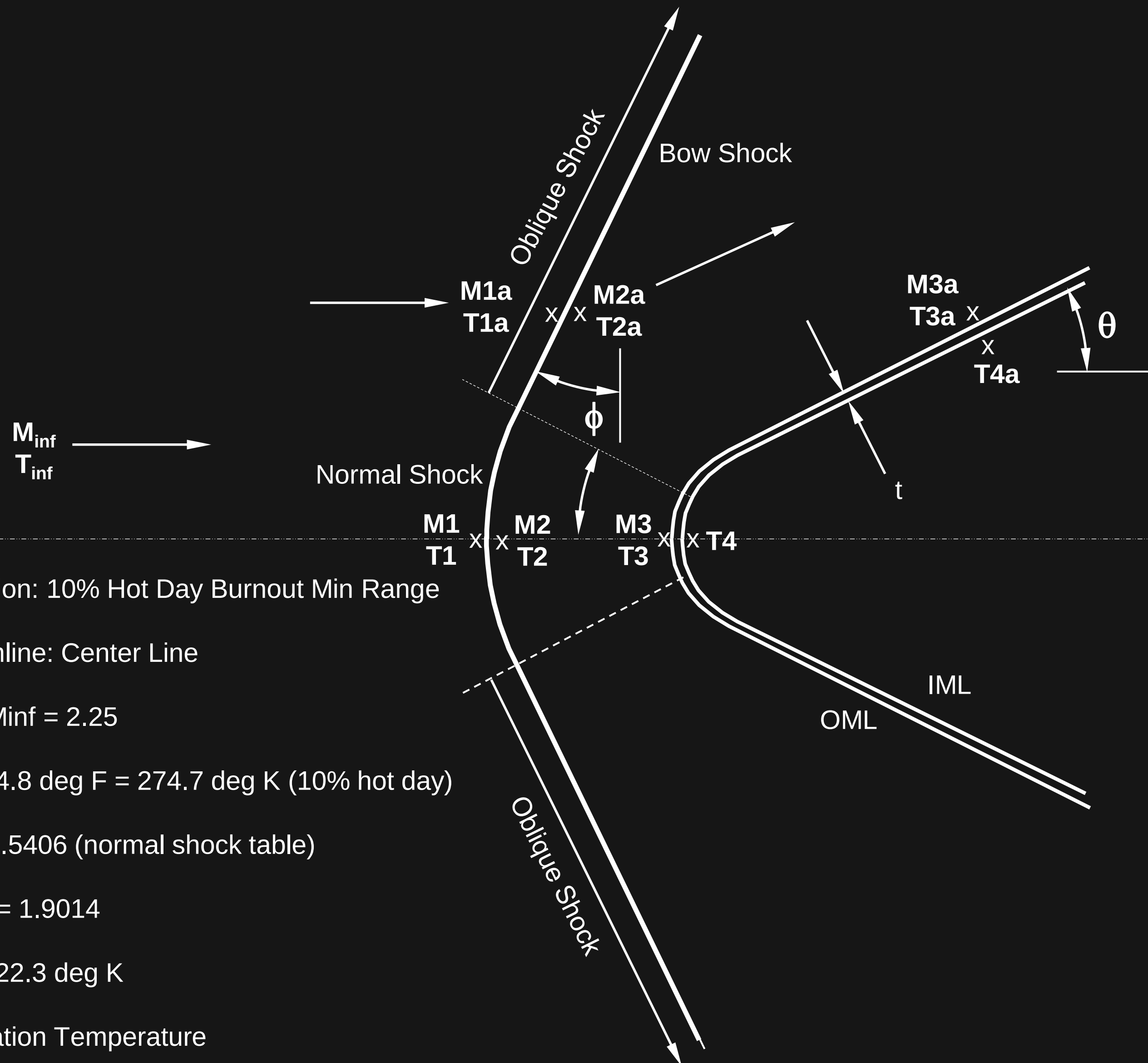
M2 = 1.6032 (oblique shock table)

T2/T1 = 1.1889

T2 = 382.9 deg K = 230 deg F

Phi = 40.4 deg

Stagnation Temperatures: Normal Shock



Condition: 10% Hot Day Burnout Min Range

Streamline: Center Line

M1 = Minf = 2.25

T1 = 34.8 deg F = 274.7 deg K (10% hot day)

M2 = 0.5406 (normal shock table)

T2/T1 = 1.9014

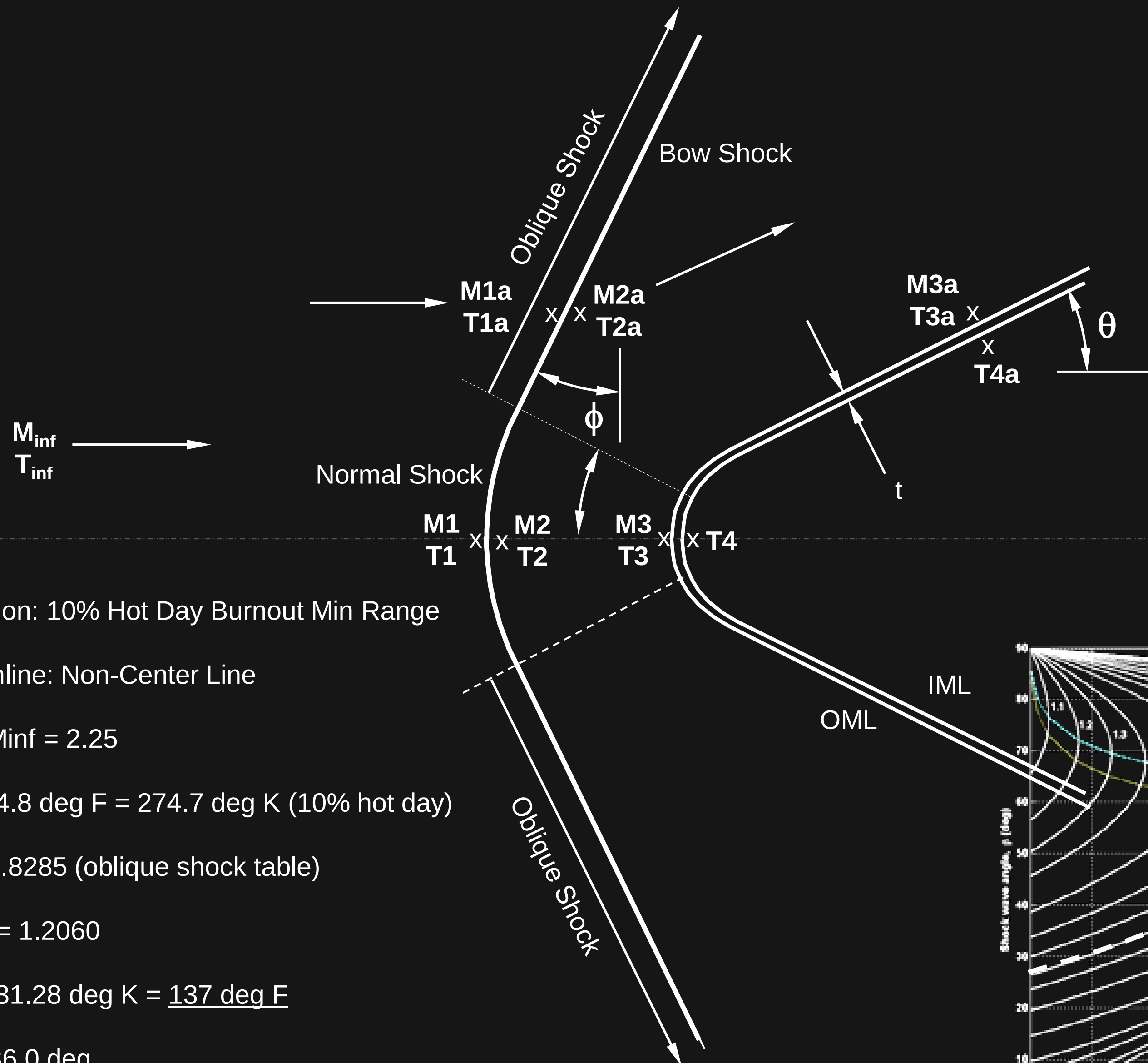
T2 = 522.3 deg K

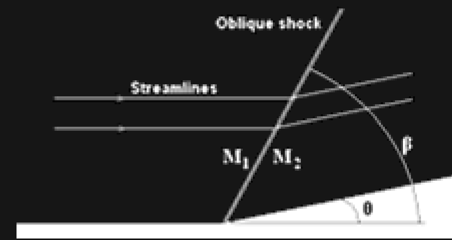
Stagnation Temperature

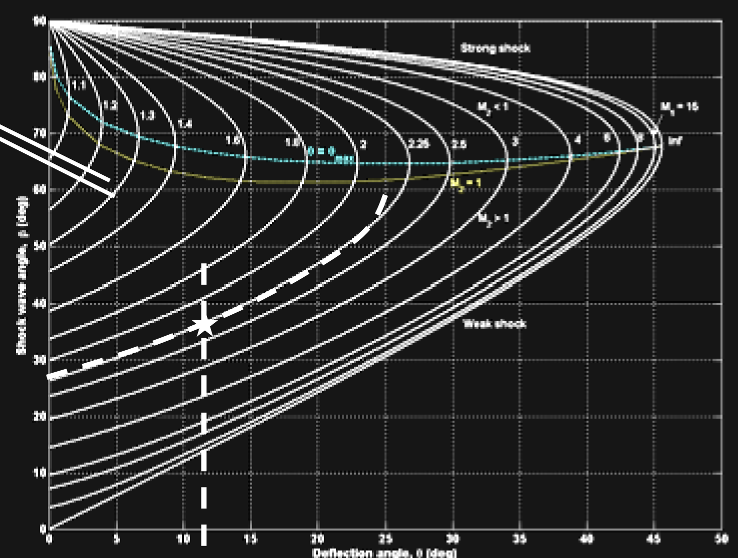
T3 = T0 = T2 (1 + ((gamma -1)/2) M2^2) = 552.9 deg K or 535.5 deg F

Compare to Recovery Temp P1 = 510 deg F => 440/535.5 = 17.8% loss (reasonable)

Stagnation Temperatures: Oblique Shock







Condition: 10% Hot Day Burnout Min Range

Streamline: Non-Center Line

M1 = Minf = 2.25

T1 = 34.8 deg F = 274.7 deg K (10% hot day)

M2 = 1.8285 (oblique shock table)

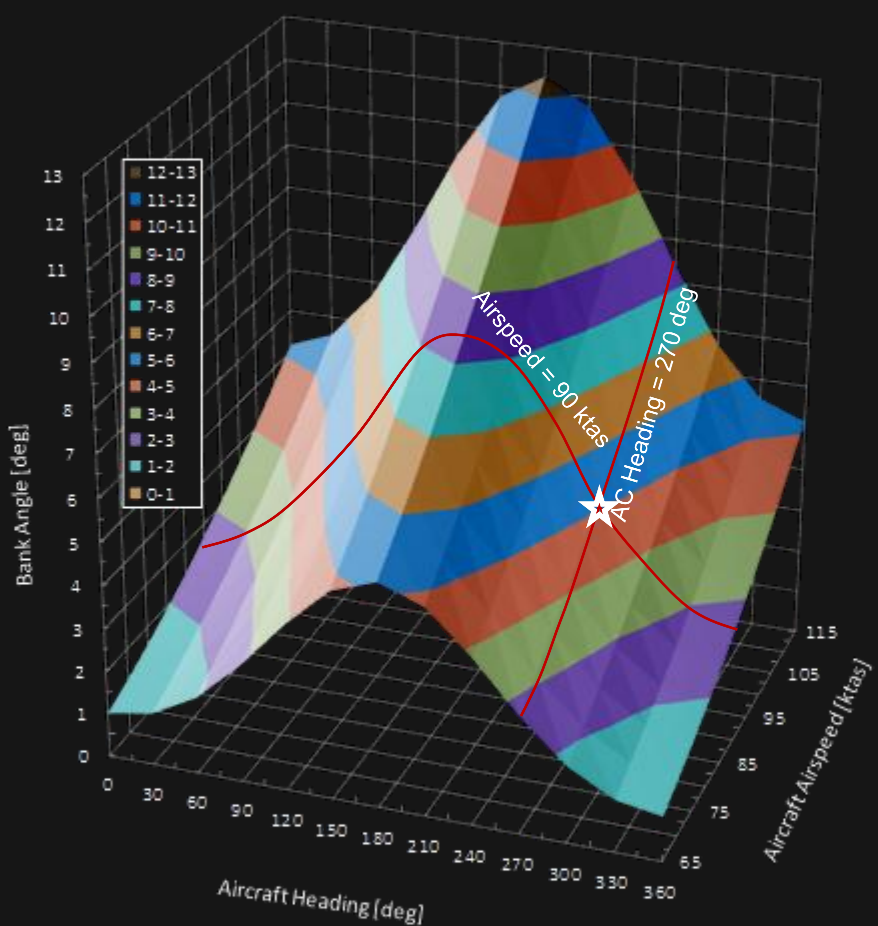
T2/T1 = 1.2060

T2 = 331.28 deg K = 137 deg F

Phi = 36.0 deg

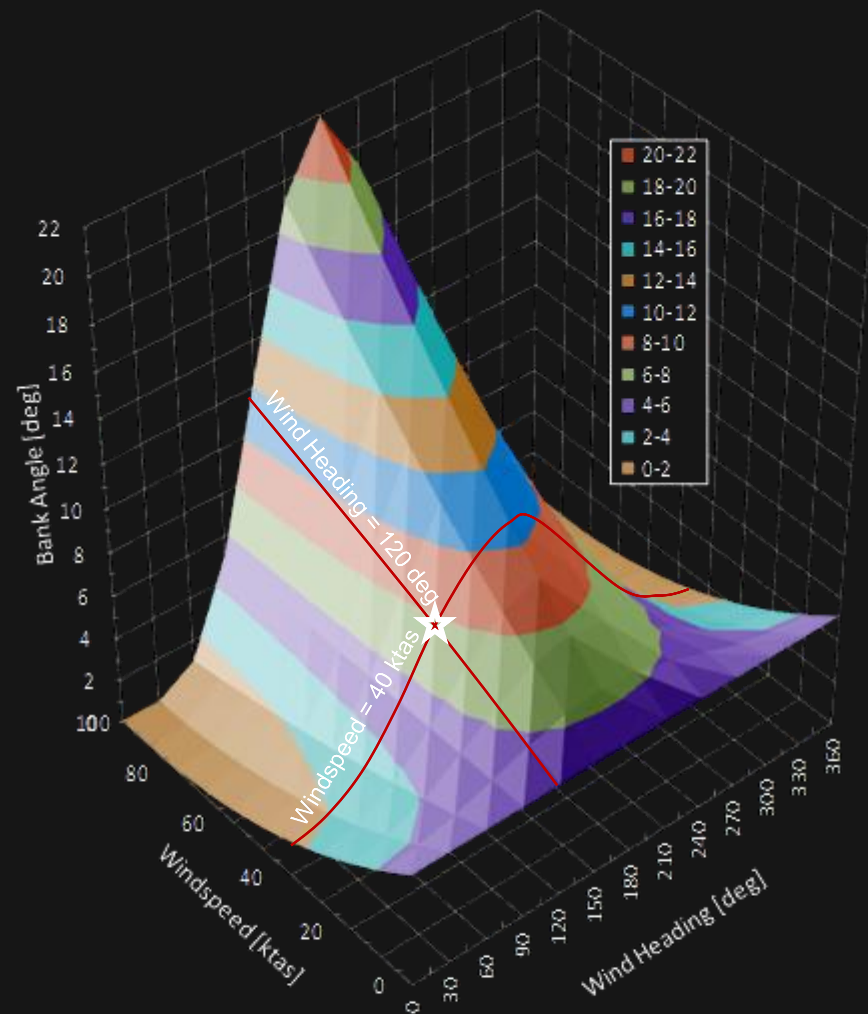
Bank Angle Study: First Order

Aircraft Sweep



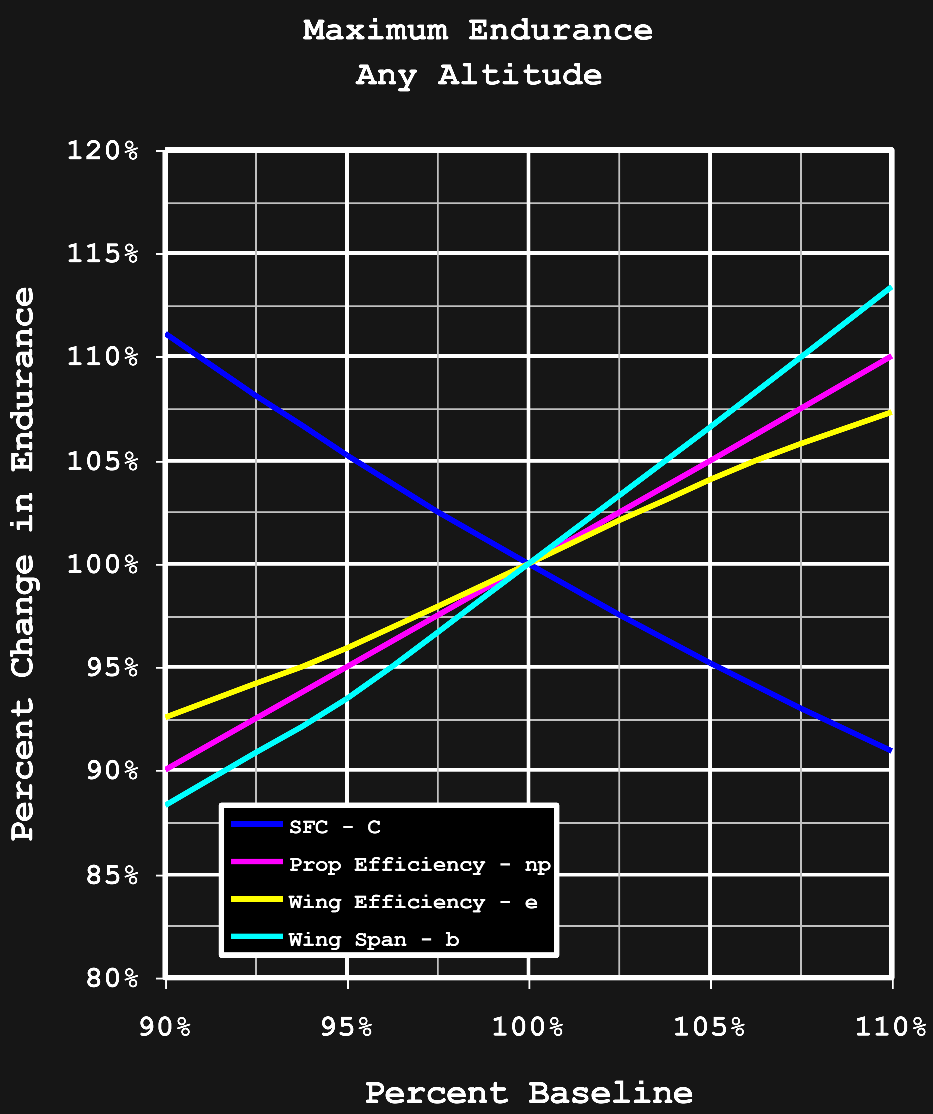
Assumptions:
Altitude = 17,000 ft MSL
Windspeed = 25 ktas
Wind Heading = 0 deg

Wind Sweep



Assumptions:
Altitude = 17,000 ft MSL
Airspeed = 90 ktas (69 keas)
Aircraft Heading = 0 deg

Sensitivity Study: Endurance



- ***Answer***
  - Larger Span and Smaller SFC, Prop and Wing Efficiencies are Better
  - Altitude Independent
- ***Assumptions***
  - Parasitic Drag Buildup with Form Factor Method
  - Used Average Dynamic Pressure for Entire Segment
  - Loiter for Prop at 87% Max L/D
- ***Sensitivities***
  - Drivers in Order of Impact:
    - *- Wing Span*
    - *- SFC*
    - *- Prop Efficiency*
    - *- Wing Efficiency*
  - Drivers are Close in Overall Impact
- ***Alternatives***
  - Cross Check with Incremental Calculations

Trade Study: Launch Qualitative

	Description	Pros	Cons
CTOL – Static Gear	Fixed tricycle gear. Use COTS wheels/axels (RC industry). Requires grass or dirt strip runway (~500 ft).	- Design already exists - Lowest technical risk	- Requires prepared runway (est. 500 ft.) - Obscures sensor view - Performance Reduction - Parasitic Drag Hit - Increase in RF Signature
CTOL – Retractable Gear	Fixed tricycle gear. Use COTS wheels/axels (RC industry). Requires grass or dirt strip runway (~500 ft).	- Vehicle designed with retracts in mind	- Requires some NRE (design already started) - Landing gear mechanism (complexity = cost) - Runway needs to be good quality
CTOL – Dolly or Cart	Drop away tricycle gear. Use COTS wheels/axels (RC industry). Requires grass or dirt strip runway (500 ft).	- Lowers aircraft weight	- Extra Loose components - Additional step in launch process & logistics
Pneumatic Launch Rail	Large wheeled launch rail (possibly on trailer).	- Repeatable launch - No Pilot training required - No prepared runway required	- Large logistical footprint - Requires significant NRE (unless we can buy one somewhere) - Mechanical reliability?
High/Push Start on Rail	Low friction Guide Rail laid on ground (in sections). Rides on rail until lift off. No active components. Aircraft relies on own engine to accelerate (helped out by a "high start" and/or push).	- Simple design compared to Pneumatic Launch Rail - Does not require prepared runway - Guide rail could float on water if need be	- Still Requires significant length (shorted than conventional Take Off though) - Requires some NRE
Sling Launch	Aircraft is spun on a tether until it reaches climb-out velocity and then it is released.	- Does not require prepared runway - Potentially lowers aircraft weight - Can choose release speed and direction - quick deployment	- New, unproven concept - Requires Significant NRE

Trade Study: Recovery Qualitative

	Description	Pros	Cons
CTOL – Static Gear	Fixed Tricycle gear configuration. Use COTS wheels/axels (RC industry). Requires grass or dirt strip runway (est. 500 ft long).	- Design already exists - Lowest technical risk	- Requires prepared runway (est. 500 ft.) - Obscures sensor view - Performance Reduction - Parasitic Drag Hit - Increase in RF Signature
CTOL – Retractable Gear	Retractable Tricycle gear configuration. Use COTS wheels/axels (RC industry). Requires grass or dirt strip runway (est. 500 ft long).	- Vehicle designed with retracts in mind	- Requires some NRE (design already started) - Landing gear mechanism (complexity = cost)
CTOL – Static Skids	Fixed TBD skid configuration. Requires grass or dirt strip runway (est. 100 ft long).	- Requires shorter runway than wheels - Possibly easier to implement Auto-Land	- Requires some NRE - Possible greater potential for damage on landing - Performance Reduction - Parasitic Drag Hit
CTOL – Retractable Skids	Retractable TBD skid configuration. Requires grass or dirt strip runway (~ 100 ft).	- Requires shorter runway than wheels - Possibly easier to implement Auto-Land	- Requires some NRE - Possible greater potential for damage on landing - Alighting gear mechanism (complexity =
Fly into a "Net"	Hanging Net of TBD design will catch the UAV as it flies into it. The engine will probably have to be turned off before impact.	- Does not require prepared runway	- High risk of damage to the UAV during recovery - Larger logistical footprint compared to conventional Landing
Sky Hook	Similar to the Boeing Scan Eagle design with appropriate tweaks to work with vehicle.	- Does not require prepared runway - Quick recovery (saved time)	- Difficult to modify vehicle to this configuration (may require significant NRE and changes) - Larger logistical footprint compared to
Deep Stall	Flight controller maintains the aircraft in deep stall (wings level) and performs a near-vertical landing. May require shock absorbers/airbags under aircraft.	- No one else is doing this on our class of UAV or bigger - If successful we might attract R&D funding for further development.	- Requires significant NRE on the flight controller - Requires some NRE for shock absorbers
Ballistic Chute	Aircraft deploys a parachute when it arrives over landing zone.	- Known method from Target Drones - Chute delpoys over landing zone - Low risk	- Tangled in chute - Space for pyro deployment device - Heavy

Trade Study: Launch & Recovery Quantitative

		Logistics Foot Print	Min Training/Skill	Low Cost	Minimum NRE	Mech Reliability	Repeatable	Min Weight	Min Impact to Useful Volume	Sensor Obscuration	Minimum Reqmts on Deployment Area	Average - Unweighted	Average - Unweighted	Average - Weighted	Average - Weighted
	Weighting	1	1	3	2	1	1	1	1	3	1				
Launch	**CTOL – Static Gear**	5	1	5	5	5	5	4	3	1	1	3.5	**92%**	52	**91%**
Launch	**CTOL – Retractable Gear**	5	1	4	4	3	5	3	1	5	1	3.2	**84%**	54	**95%**
Launch	**CTOL – Dolly or Cart**	4	1	4	4	4	4	5	3	5	1	3.5	**92%**	57	**100%**
Launch	**Pneumatic Launch Rail**	1	3	1	1	2	5	5	4	5	5	3.2	**84%**	45	**79%**
Launch	**High/Push Start on Rail**	3	3	3	3	4	4	5	4	5	4	3.8	**100%**	57	**100%**
Launch	**Sling Launch**	3	2	3	1	2	3	4	3	5	5	3.1	**82%**	48	**84%**
Recovery	**CTOL – Static Gear**	5	1	5	5	4	5	4	3	1	1	3.4	**97%**	51	**94%**
Recovery	**CTOL – Retractable Gear**	5	1	4	4	3	5	3	1	5	1	3.2	**91%**	54	**100%**
Recovery	**CTOL – Static Skids**	5	1	5	3	5	4	4	4	1	2	3.4	**97%**	49	**91%**
Recovery	**CTOL – Retractable Skids**	5	1	4	3	4	4	3	2	5	2	3.3	**94%**	54	**100%**
Recovery	**Net**	2	4	3	2	3	3	4	4	5	5	3.5	**100%**	53	**98%**
Recovery	**Sky Hook**	2	4	3	1	3	3	3	4	5	5	3.3	**94%**	50	**93%**
Recovery	**Deep Stall**	5	5	3	1	2	2	3	4	5	5	3.5	**100%**	52	**96%**
Recovery	**Ballistic Chute**	3	5	3	1	5	5	2	1	5	5	3.5	**100%**	52	**96%**