Dynamics of Flight

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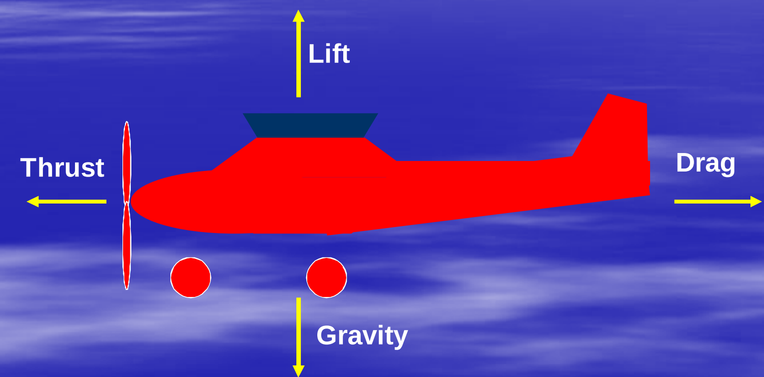
09 10

Stuff to Talk About

- Recap of 4 forces
- 2 Ways to look at lift
- Aircraft Balance
- Stall
- Trainer to 2nd plane transition
- Takeoff
- Aircraft design considerations
- Propellers
- The Sun
- Crash site recovery

Recap of 4 Forces



2 Ways to Look at Lift

- 1^{st} Way - Traditional (Bernoulli)

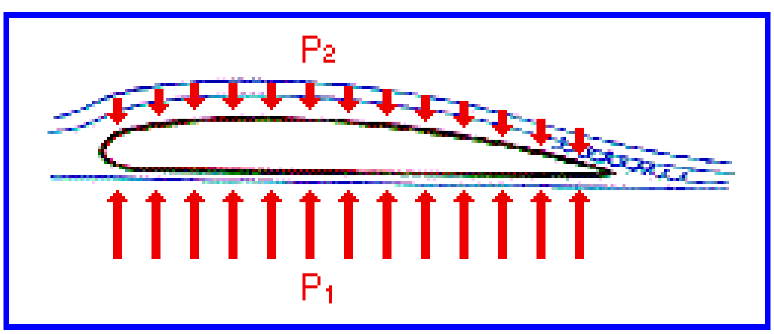
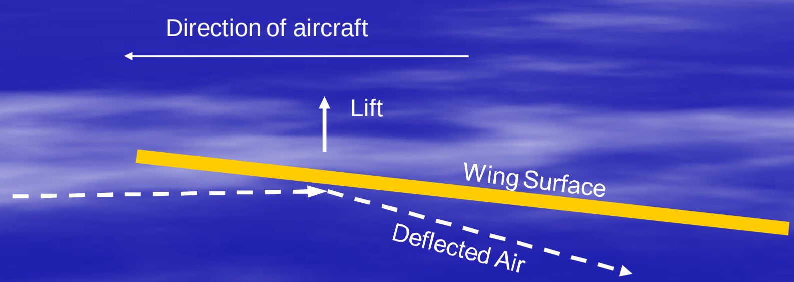


Figure 4-1 How lift produces?

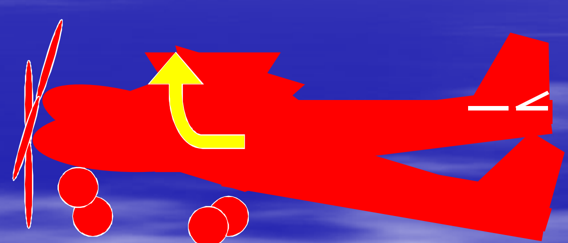
2 Ways to Look at Lift

- 2^{nd} Way - Dynamic Lift (Reaction lift)
- This is why a flat wing or symmetrical wing can fly.



Control Surface Influence

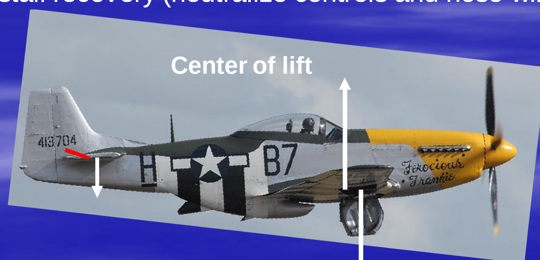
- Control surface deflection causes rotation about an axis of the aircraft.



Similar principle applies to Roll and Yaw axes

Balance

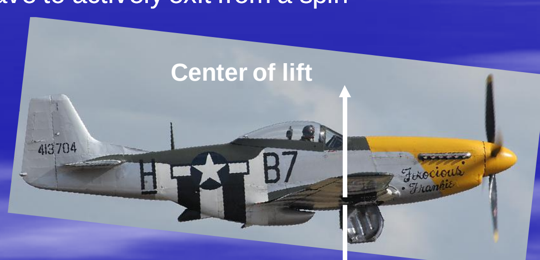
- Balance according to the published point for the design.
  (Usually CG at 25% to 30% of MAC. Calculator available on rccd.org).
  If there is a range, start at the forward recommended point.
- A slightly forward CG
  - Safer, more stable flight
  - Faster landing speed (higher stall speed)
  - More predictable stall
  - Better stall recovery (neutralize controls and nose will drop)



Level flight maintained by slight up trim But requires some down elevator when inverted

Balance (cont.)

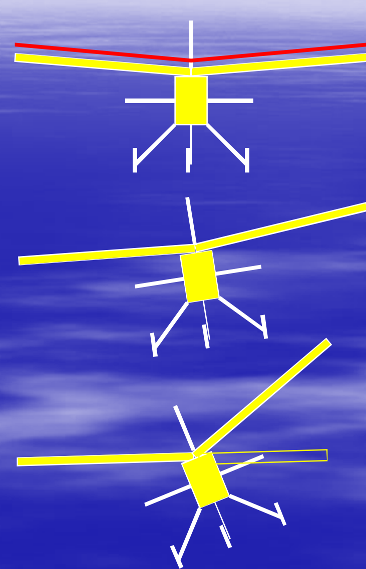
- A slightly rearward CG
  - More neutral flight (less down elevator required when inverted)
  - Slower landing speed (lower stall speed)
  - Less stall warning
  - May have to actively exit from a spin



CG changes as fuel is used

- "A nose-heavy plane flies poorly; a tail-heavy plane flies once."

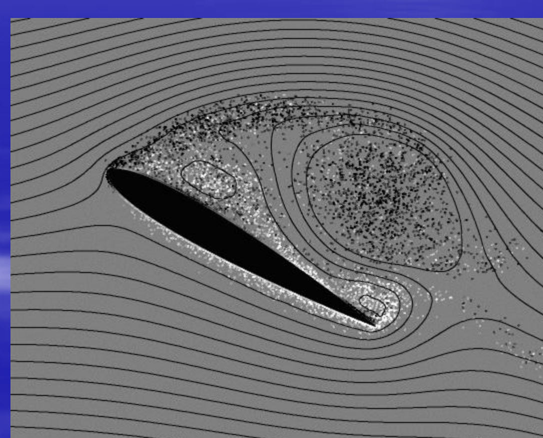
Dihedral



- Aids lateral “stability” (roll correction)
- Aids turning
  - Show me!

Stall

- Stall occurs when the wing stops flying
- This can happen at any speed
- What happens:



Stall (cont.)

- Normally, up elevator causes nose to pitch up and direction to change.

Stall (cont.)

- With sufficient elevator authority, the nose can be pitched up without the aircraft changing flight direction.

Wing Wash-out

- What is it?
  – The wings have a slight twist from root to tips, so that the tips are aimed slightly down. As angle of incidence increases, the root stalls before the tips. Aileron control is maintained.

Stall (cont.)

- On a good trainer design:
  – Small control surfaces don't allow vast aircraft attitude changes.
  – Wing root stalls before wing tip. (from wing washout)
    - This causes nose to drop while ailerons continue to have effect. (assuming balance considerations mentioned)
  – On most trainers a stall is usually followed by a wings-level drop of the nose; speed increases; flight resumes.
- If a wing tip stalls first (usually one wing before the other), that wing drops and we can get a snap.
  (This can be desirable for some aerobatics)
- Large aileron deflection can cause stall of a wing.
  – The down aileron trying to lift that wing induces a stall.
  – That wing <u>drops</u> (reverse of what you want!)
  – That's when we hear "I got hit with radio interference!"

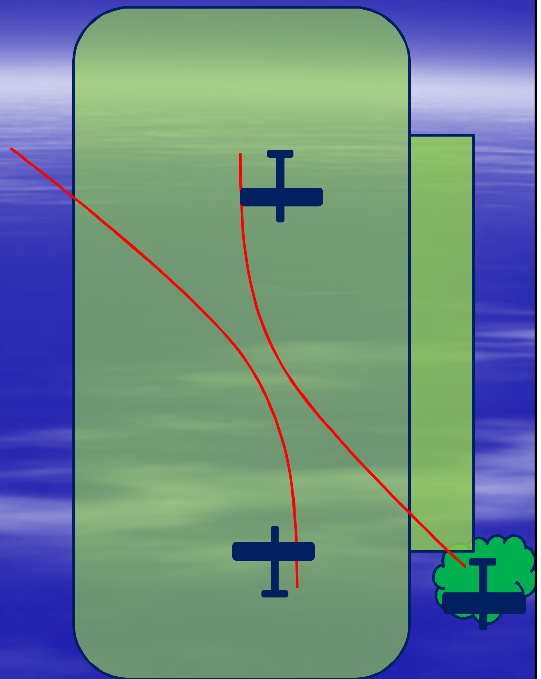
Stall/Spin Recovery

- Neutralize sticks first
- Add some throttle (about ½ throttle)
- Aim nose down (if altitude allows)
  - Throttle and descent will get air flowing over the wings and control surfaces.
- If required, add rudder in opposite direction to spin
- Fly out of the descent WITHOUT excess elevator!

Takeoff

- If stall occurs during take-off, results are fairly predictable! And not pleasant.
- Trainers are designed to be forgiving:
  - High-lift wings and wing tips that stall last permit slow flight speeds, and therefore low stall speeds.
  - If a trainer does stall shortly after takeoff, there is a “wings-level drop of the nose; speed increases; flight resumes”. That is if there is enough room; or a prop-stopping, nose-wheel bending dive back to the runway, if not.
- Second Planes often have:
  - Higher wing loading (Warbirds) which demand higher flight speeds.
  - Larger control surfaces with more authority.
  - Less forgiving stall characteristics, that may be required for aerobatics.
  - Stronger tendency to swing left (discussed in detail later)

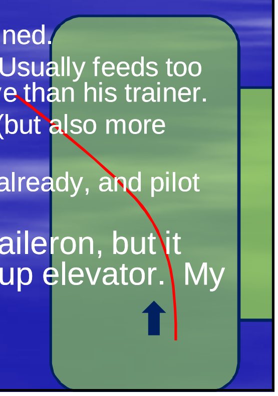
Take-off



Takeoff (cont.)

- Second (or 3rd or 4th)Plane - Scenario one:
  - A second plane is often the pilot's first tail-dragger.
  - Plane veers to left during acceleration. Pilot has not really mastered rudder control.
  - Pilot pulls back on elevator stick at the same ground speed as his trainer, to get the thing flying. Usually feeds too much elevator because the plane is more sensitive than his trainer. Or pilot has full up for slow-speed ground steering.
  - So the nose pitches up and speed is not maintained.
  - He feeds right aileron to "correct" the left steer. Usually feeds too much aileron because the plane is more sensitive than his trainer.
  - The left aileron goes down, to produce more lift (but also more drag) and that wing stalls.
  - Left wing drops (remember plane is veering left already, and pilot has applied right stick)

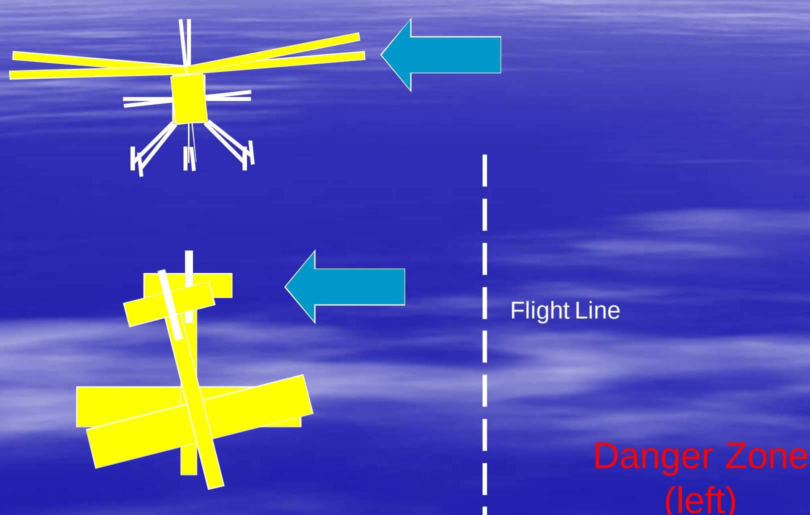
"The plane would not respond. I had full right aileron, but it went left. The nose dropped and I had full up elevator. My radio musta got hit!"
  - Hello cartwheel! Get the garbage bag!

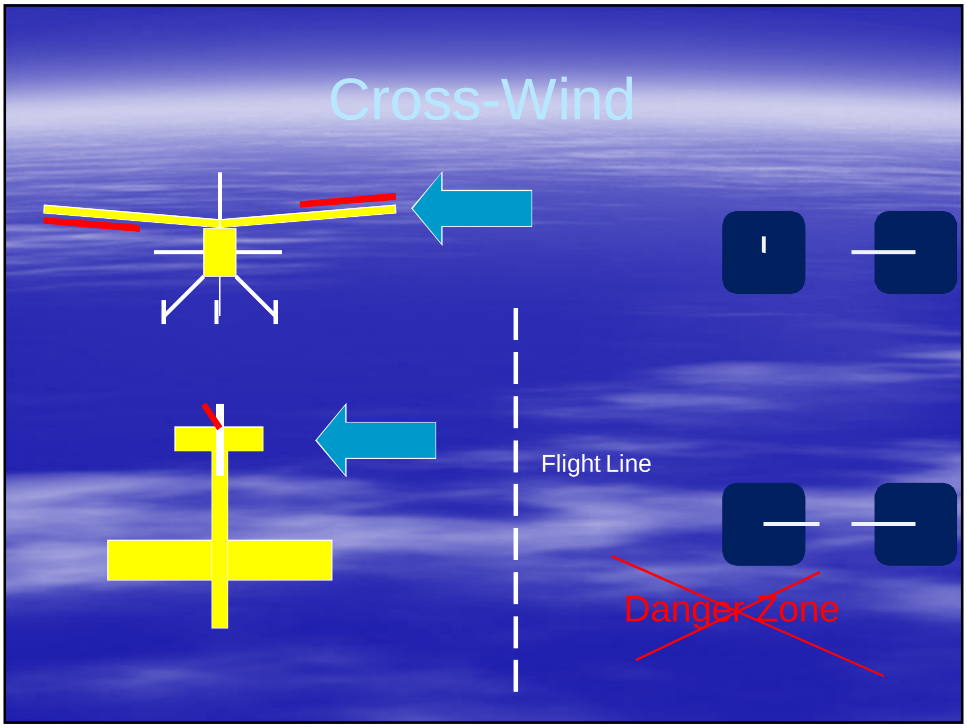


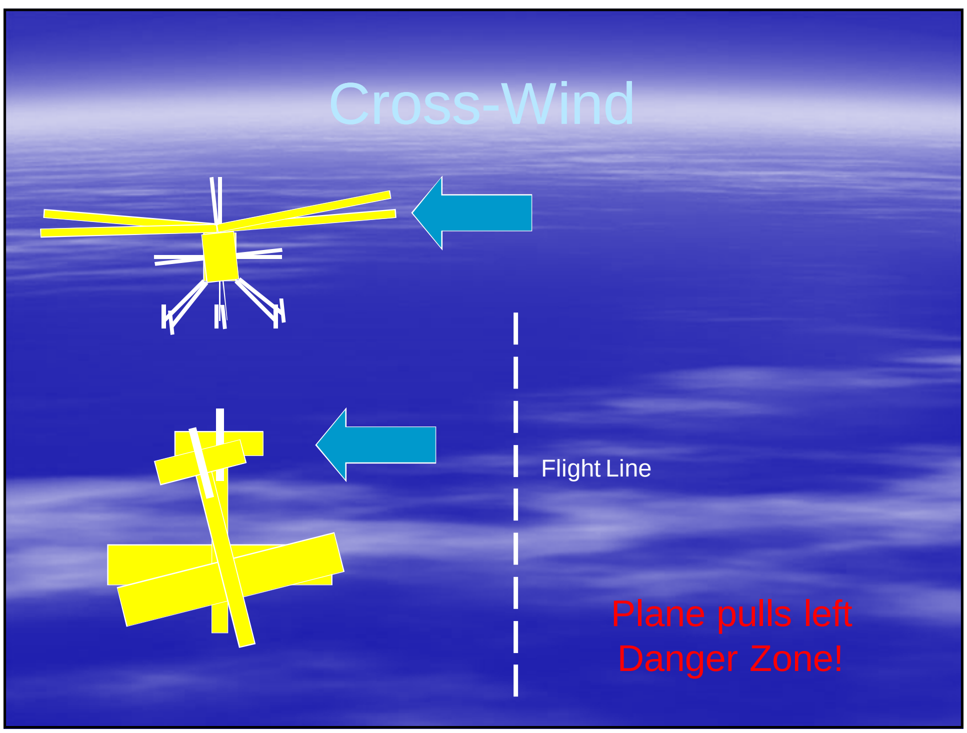
Take-off Hazards

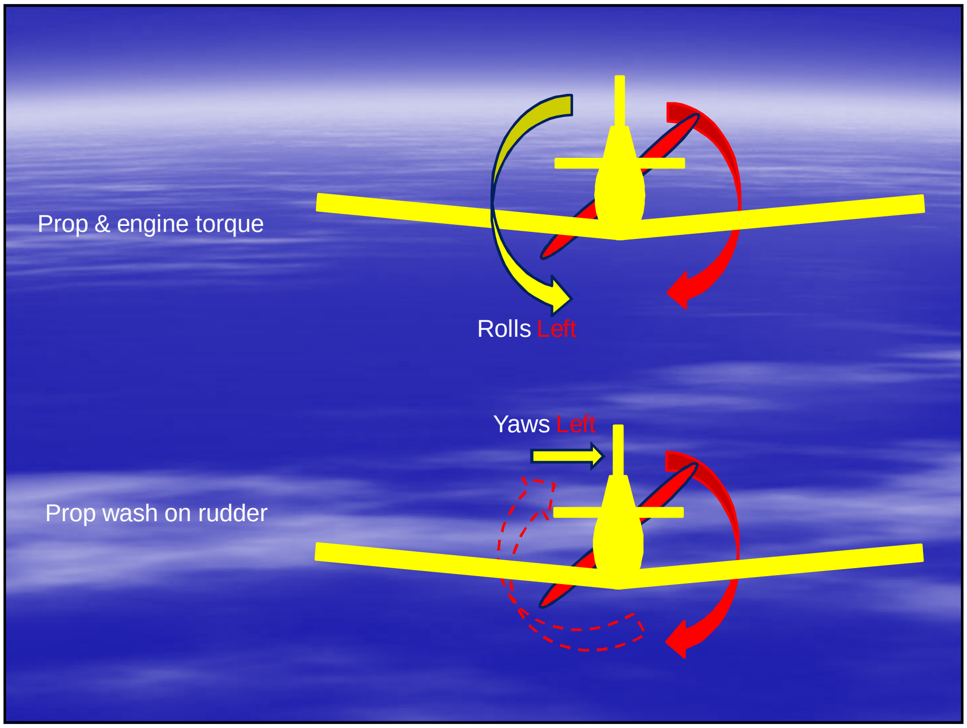
- Cross wind
- Engine/prop torque
- Prop wash on rudder
- P-factor
- Gyroscopic precession

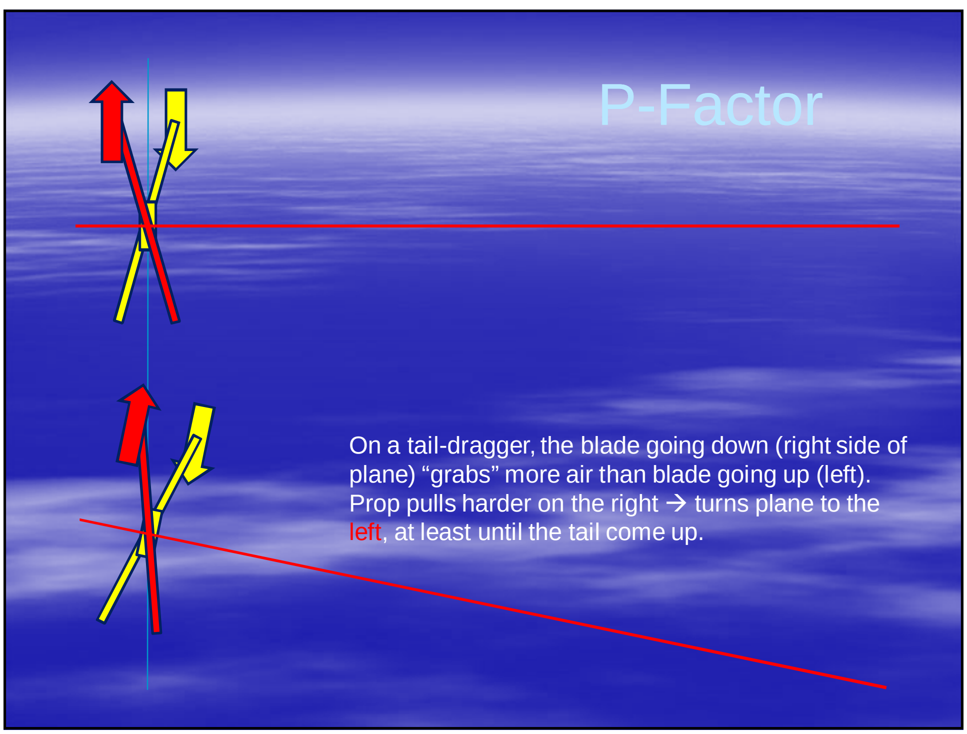
Cross-Wind



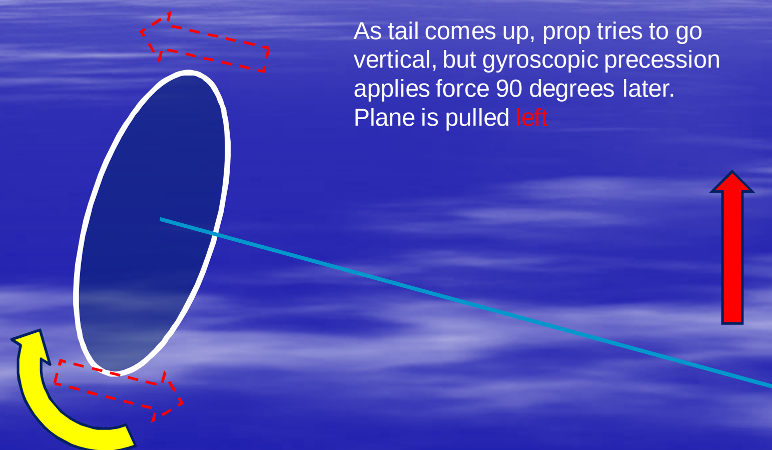

Cross-Wind
Flight Line
Danger Zone


Cross-Wind
Flight Line
Plane pulls left
Danger Zone!


Prop & engine torque
Rolls Left
Yaws Left
Prop wash on rudder


P-Factor
On a tail-dragger, the blade going down (right side of plane) “grabs” more air than blade going up (left). Prop pulls harder on the right → turns plane to the left, at least until the tail come up.

Gyroscopic Precession



As tail comes up, prop tries to go vertical, but gyroscopic precession applies force 90 degrees later. Plane is pulled left

Take-off Hazards

- With a South Wind → 5 factors pull left!!!
  - Cross wind
  - Engine torque
  - Prop wash on rudder
  - P-factor
  - Gyroscopic precession
- COMPENSATE
  - Set up slightly right
  - Apply right rudder
  - Steer with the rudder
  - Get more speed before lift-off

Takeoff (cont.)

- Second Plane - Re-take the scene:
  - A second plane is often the pilot's first tail-dragger.
    Practice taxiing at various speeds using the rudder.
  - Usually requires up elevator during taxiing to avoid nosing over.
    Practice gradually releasing elevator as speed builds up.
  - On take-off as the plane veers to left during acceleration
    Hold direction with rudder. (visualize this before throttle-up)
  - Accelerate longer, letting the tail come up.
    (remember: release elevator!)
  - When the mains bounce - give a touch of elevator.
    Don't climb for the clouds!
  - With the plane flying well above stall speed -
    Aileron control will be easier to "feel", but keep stick movement moderate.
    Begin to bank away from flight line.

Aircraft Considerations

Easy		Difficult
5 oz/sq ft	Wing Loading	35 oz/sq ft
Long tail	Fus' Length : Wing Span	Short-coupled
Constant chord	Wing taper	Highly tapered
Wash-out	Wing Twist	None
Dihedral	Wing angle	Flat or Anhedral
High wing	Wing position	Low wing
At or ahead of wing LE.	Tail dragger wheels	Back towards CG
Close to level	Parked angle	Nose high
Wide	Undercarriage width	Narrow
Slightly Nose-heavy	CG	Nose-heavy or Tail-heavy

These are very general considerations, some of which can be compensated for in design.

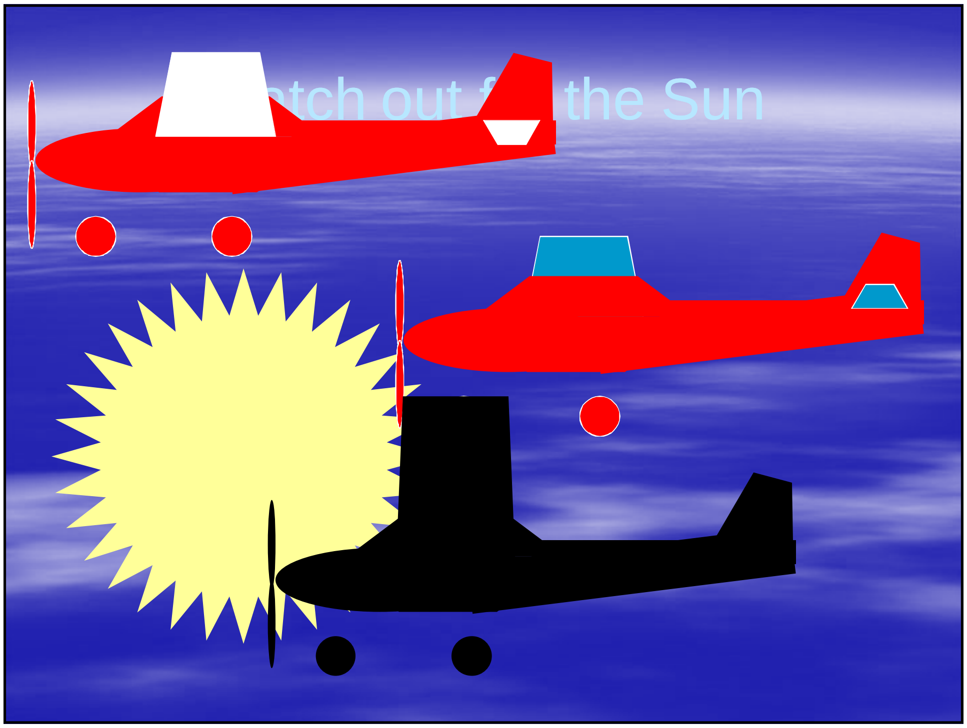
Prop' Considerations

- Props are specified as Diameter x Pitch.
  - example: 11x6 has 11 inch diameter & 6 inch pitch.
  - Pitch is the theoretical forward movement during one revolution.
- Prop Diameter to pitch ratio of about 2:1 is typical for sport flying/ (11x6 for a .46 engine)
- Use lower ratio approaching 1:1 for speed (9x8)
- Use higher ratio nearer to 3:1 for low-speed pulling power (12x4)
- To keep rpm roughly the same, an increase of 1 inch in diameter, must be offset by a decrease of 1 inch in pitch; and vice versa. 10x7=11x6=12x5.
  (This is a rough rule-of-thumb for most sport plane prop sizes)

PROPELLER DIAMETER, TIP SPEED, RPM AND NOISE

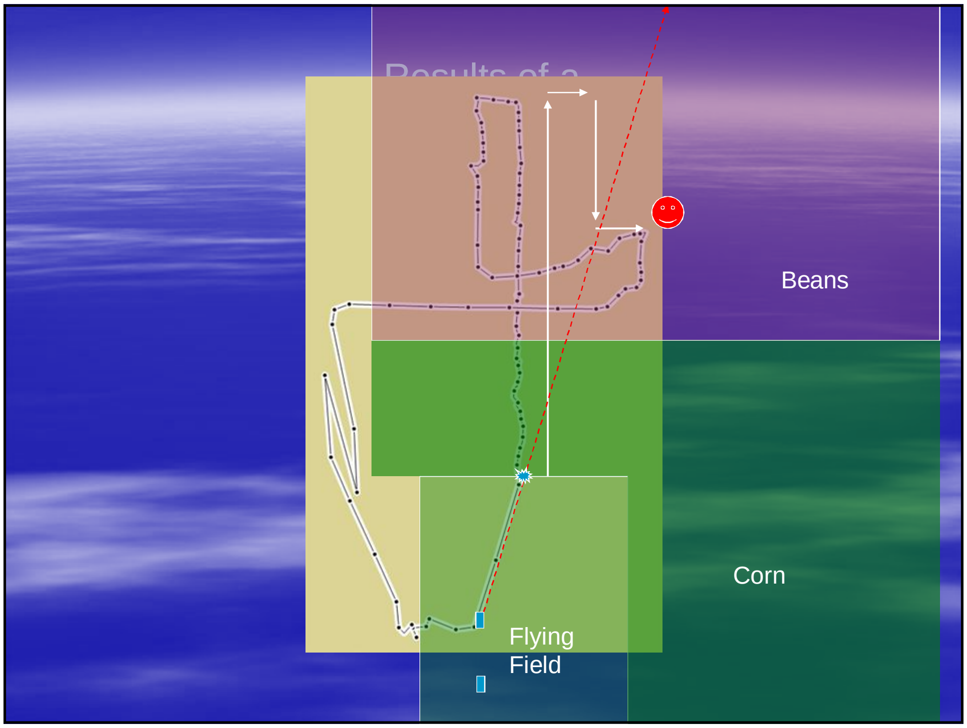
	Tip	Speed										RPM		(x1000)										
Prop Diam	mph 400	mph 380	Prop Diam	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	R	P M											Tip Speed											
5.5	24446	23224	5.5	82	98	115	131	147	164	180	196	213	229	245	262	278	295	311	327	344	360	376	393	409
6	22409	21289	6	89	107	125	143	161	178	196	214	232	250	268	286	303	321	339	357	375	393	411	428	446
7	19208	18247	7	104	125	146	167	187	208	229	250	271	292	312	333	354	375	396	416	437	458	479	500	521
8	16807	15966	8	119	143	167	190	214	238	262	286	309	333	357	381	405	428	452	476	500	524	547	571	595
9	14939	14192	9	134	161	187	214	241	268	295	321	348	375	402	428	455	482	509	535	562	589	616	643	669
10	**13445**	**12773**	**10**	**149**	**178**	**208**	**238**	**268**	**297**	**327**	**357**	387	**416**	**446**	**476**	**506**	**535**	**565**	**595**	**625**	**654**	**684**	**714**	**744**
11	**12223**	**11612**	**11**	**164**	**196**	**229**	**262**	**295**	**327**	**360**	**393**	**425**	**458**	**491**	**524**	**556**	**589**	**622**	**654**	**687**	**720**	**753**	**785**	**818**
12	**11205**	**10644**	**12**	**178**	**214**	**250**	**286**	**321**	**357**	**393**	**428**	**464**	**500**	**535**	**571**	**607**	**643**	**678**	**714**	**750**	**785**	**821**	**857**	**892**
13	10343	9825	13	193	232	271	309	348	387	425	464	503	541	580	619	657	696	735	773	812	851	890	928	967
14	9604	9124	14	208	250	292	333	375	416	458	500	541	583	625	666	708	750	791	833	875	916	958	1000	1041
15	8964	8515	15	223	268	312	357	402	446	491	535	580	625	669	714	759	803	848	892	937	982	1026	1071	1116
16	8403	7983	16	238	286	333	381	428	476	524	571	619	666	714	762	809	857	904	952	1000	1047	1095	1142	1190
17	7909	7514	17	253	303	354	405	455	506	556	607	657	708	759	809	860	910	961	1011	1062	1113	1163	1214	1264
18	7470	7096	18	268	321	375	428	482	535	589	643	696	750	803	857	910	964	1017	1071	1125	1178	1232	1285	1339
19	7077	6723	19	283	339	396	452	509	565	622	678	735	791	848	904	961	1017	1074	1130	1187	1244	1300	1357	1413
20	6723	6387	20	297	357	416	476	535	595	654	714	773	833	892	952	1011	1071	1130	1190	1249	1309	1368	1428	1487

Target speed: Less than 380 mph, for quieter operation



The Dreaded Magnetic Woods

- If your plane goes down:
  - Fly it as far into the crash as possible. Don't give up until you <u>know</u> it's crashed
  - If you can't see the crashed plane, don't look away until you have a "fix" on the line of the crash. (eg: flight station 4, to tallest dead tree)
  - Explain the line to someone else.
  - Walk as straight on that path as possible. Use a GPS if you have one. If not found, walk back parallel and keep repeating.
- Retrieve as much of the wreck as possible:
  - Refrain from damaging it further.
  - Study the evidence to help identify the cause.
  - Make the discard/repair decision after about a week.



What we Covered:

- Recap of 4 forces
- 2 Ways to look at lift
- Aircraft Balance
- Stall
- Trainer to 2nd plane transition
- Takeoff
- Aircraft design considerations
- Propellers
- The low sun
- Improve crash recovery chances

Some Things to Try:

- On any plane with dihedral, at a safe altitude, fly with rudder and elevator only (no ailerons). See if you can do 3 laps. How about 3 horizontal eights?
- At a safe altitude, slow down and gradually add elevator until plane stalls. Does nose drop; or a wing drop? (to recover, neutralize both sticks then add throttle (about ½).
- Always do this (stall) on one of the first flights of a new plane. Better to find out high than on dead-stick landing!
- At a safe altitude, ¾ throttle, give sudden full up elevator. Does the plane do tight loops or stall/snap? (same recovery)
- On a familiar plane, practice using rudder during take-off
- On a familiar plane, practice gentle climb-out from take-off.

Aviation's Perfect Record:

"We have never left one up there"!

njh