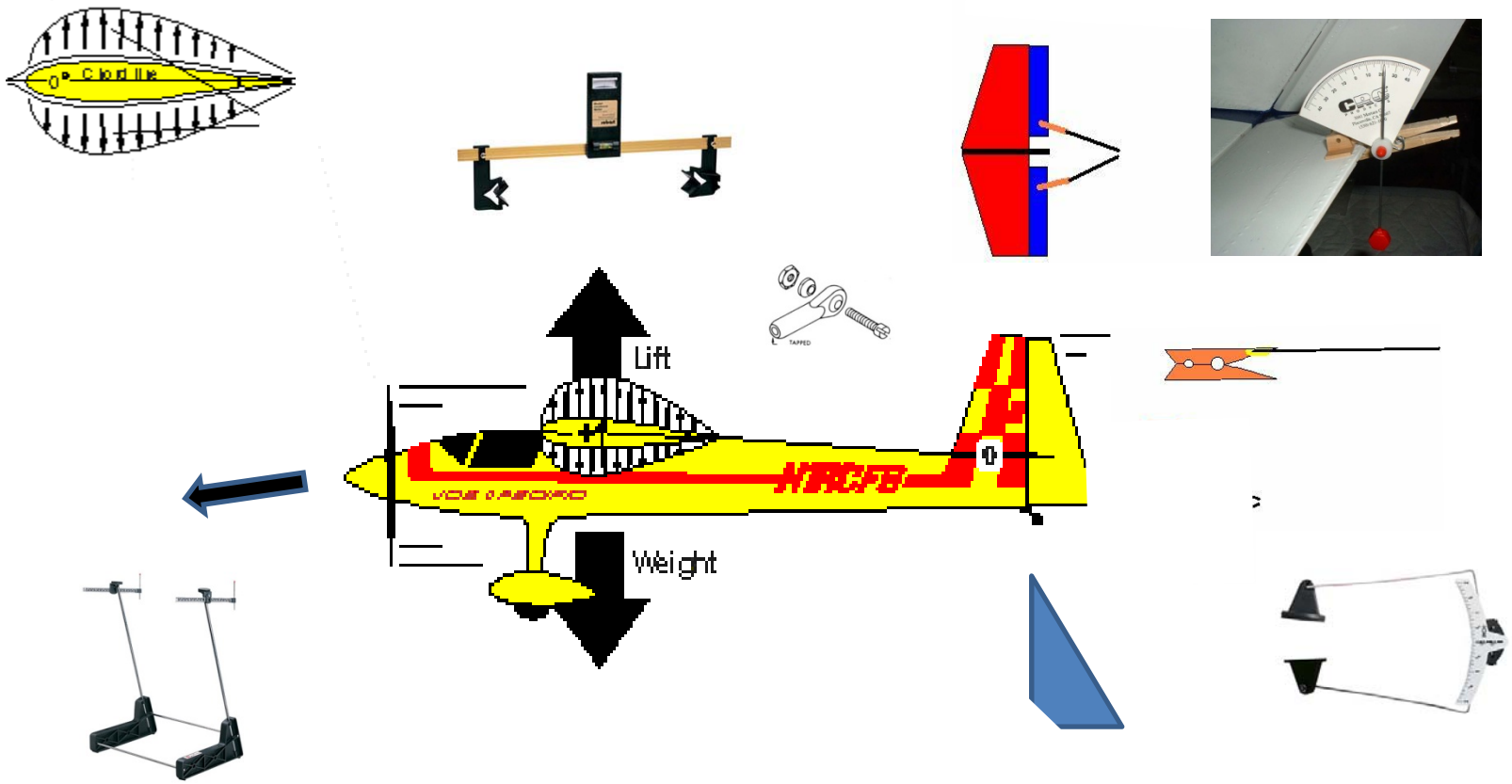
Model Aircraft Setup & Trimming Basic



Roger Hammel - September 9, 2008

Goals of Setup & Trimming

- Basic
  - Hands off – straight & level flight
  - Predictability & repeatability
  - Control – enough stability balanced w/ desired maneuverability. Minimize pilot "corrections"
  - No adverse & unpredictable aircraft actions & behaviors
  - Cost balance with performance & weight

- Advanced
  - Aerobatic – non-level flight – maneuvering
  - Deal with "coupling" issues
  - Special Cases

- Other ??

- Inescapable conclusions –
  - No single "right" answers
  - Someone always knows more than you do
  - There is usually a different way of viewing the problem

Setup & Trimming Scope

- What is included in setup & trimming ?
    - Alignment
    - Power vs. Weight & prop
    - CG Location
    - Incidences
    - Control Surfaces
    - Thrustline Settings
    - Computer Radio Capabilities
        - Dual Rates
        - Exponential
        - Mixes
    - Flight testing from Maiden Flight
- When does setup & trimming start ?
- When does setup & trimming stop ?

Tools of the Trade

- General –calculator, plane stand, soft shims, & **O.F.K.**
- Alignment - cut corner triangles, string, tape, pins & ruler
- Powerplant & prop – scales, tach, pitchmeter, ruler
- CG position – balancing “machine”
- Wingloading – scales & ruler
- Control Surfaces – throwmeter, pointer sticks
- Servos – servo tester/programmer, pointer
- Incidences – incidence gauges
- Thrustline – reference plane, ruler, incidence meter,

O.F.K. = Other Folks Knowledge

- AMA http://www.modelaircraft.org/
- AMA Special Interest Groups
  - NSRCA - http://nsrca.us/
  - IMAC - http://www.mini-iac.com/
- AMA R/C Clubs & Club members
- Online Groups & Forums
  - RC Universe http://www.rcuniverse.com/
  - RC Groups http://www.rcgroups.com/
  - E-Zone http://www.ezonemag.com/
  - Wattflyer http://www.wattflyer.com/forums/
  - Flying Giants http://www.flyinggiants.com/
- Monthly Publications
  - AMA's Model Aviation
  - RC Reports
  - Quiet Flyer
- Books
  - Mastering Radio Control Flight – Scott Stoops
  - Several 1st US Flight School Books – David A Scott
  - 3 Books by Don Apostolico: Proficient Flying, Crosswind Flying, Gas Engines & Giant Planes
- Other interesting sites
  - Airfoil simulator - http://www.grc.nasa.gov/WWW/K-12/airplane/foil2.html
  - Setup tips - http://www.geistware.com/rcmodeling/aerobatics/setup.htm

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Alignment

- Follow instructions, plans or manual !!!!

- Wings
  - Top View – square to fuselage center datum line (string method)
  - Front View – equal dihedral - left vs. right. Shim or recut fuselage side.
  - Side view (incidence) - covered later – Shim or recut fuselage side
  - Undesired & uneven warpage – Visually inspect, measure to reference plane (flat table) to discover Left vs. Right differences from warpage

- Tail Feathers
  - Horizontal Stabilizer –

    Top view – similar to wing

    Front View - Orthogonal to fuselage vertical plumbline. Cut corner triangle

    Side view - Incidence – (Covered later) shim or cut fuselage
  - Vertical Stabilizer -

    Top View – parallel to fuselage centerline. String & pin method

    Rear /Front View - Parallel to fuselage vertical plumbline

- Thrustline – Use manufacturers recommendations … (covered later)

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Power & Powerplant vs. Weight & Prop selection

- Engine selection at heart of setup. May influence :
  - Aircraft weight & balance
  - Servo & equipment placement in airframe
  - Fuel load
  - Wallet load $$
- Can you have too much power ? 2 schools of thought:
  - No – power absolves all sins. 3D influence. Unlimited vertical. Macho.
  - Yes – Price of power → weight → balance → more weight → higher wingloading → higher flying speed → maneuverability penalty
  - More power @ same overall weight – almost always good. Duh!
- Decision ?
  - Individual preferences dictate . No "right" answer for all cases.
  - What is your flying style ??
  - Caution: Manufacturer's suggestions may often result in underpowered plane.
  - Suggest consulting O.F.K. But with large dose of caution.
  - Personal examples – UltraStick 40, UCD46; Venus II.
- Propeller considerations
  - Fly style - 3D, Funfly → lower pitch larger diameter; -Sport & Aerobatics → higher pitch smaller diameter.
  - Determine engine manufacturer prop recommendations
  - Match pitch speed of prop with speed expectations for plane
    Pitch Speed (mph) = Krpm x pitch (inches) x .95
  - For equivalent loads on motor from different props - consult Jim/Arlen's propload calculator formula. Rough rule of thumb → Change of 1" D = 2" pitch
  - Consider drag characteristics of airframe
  - Prop changes → unanticipated effects & coupling during aerobatics

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Stability - Primer

- **Stability** = ability of an aircraft to return to original position if involuntarily displaced
  - Natural restorative force counteracting involuntary position or movement
    - Gravity action
    - Aerodynamic
  - Stability vs. Maneuverability - inversely proportional

- **Keys :**
  - **Pitch stability** - Horizontal Cp aft of CG (Aerodynamic - dart) – Can be "fatal" if not followed
  - Yaw stability – Vertical Cp aft of CG (Aerodynamic - dart) – Can be "fatal" if not followed
  - Roll stability – Horizontal Cp above Cg (Gravity - pendulum), Dihedral (aerodynamic) – Usually can "live with instability" via aileron corrections.

Optimal CG location:

It's all just a matter of balance…

- CG location
  - CAVEAT - "Nose heavy planes fly poorly, tail heavy planes fly once…"
  - Acceptable CG must be in front of Cp for unassisted stable flight – dart analogy

    CG – not single "point", rather "range" of acceptable "points", all with tradeoffs
    CG further aft, more maneuverable, less stable. Snaps & spins easier.
    CG further forward, less maneuverable, more stable. Axial rolls easier
  - Initial location: Consult plans & O.F.K. for CG location inputs. Helpful website:

    http://www.geistware.com/rcmodeling/cg_super_calc.htm
  - Other Rules of thumb

    Initial CG at "thickest" part of wing, often on spar or slightly forward
    Initial CG range – 25% to 35% M.A.C. 25% is safer
    Cp of wing (only) usually about 25% chord. Cp of horizontal stab @25% stab chord.
    Overall Cp → relative surface areas of stab vs. wing & distance between them
      Large horizontal tail feathers vs. wing → more rearward CG allowable
      Long tail moment arm distance → more rearward CG allowable
    High "normal" throws → more conservative (forward) initial CG
  - Flying style influences choice –

    3D – well toward tail heavy (helps "stalled flight" maneuvers)
    Pattern – neutral to slightly tail heavy
    Sport – neutral to slightly nose heavy
    Trainers – nose heavy (safe)
  - **KEY** - Plan for CG adjustments. Move components vs. add weight.
- The model should balance OK before flight trimming starts. **Lateral** balance too.
- Iterative process - If CG changed, other trim parameters must be rechecked.
- Flight testing – Test-in "right" CG (close) first.

Optimal CG location: Testing Methods

- Flying tests for approximate CG location (assumes proper wing incidence, horizontal stab incidence & thrustline setup). ...Iterative process....
  - Roll into inverted flight at cruise speed
    a) Considerable "push" of elevator required for level flight → nose heavy
    b) If any pull is required → tail heavy (assuming no excessive downthrust)
    c) No pull or push → slightly tail heavy, may be OK for some fliers
    d) If slight push is required, balance is close
  - Roll into vertically banked turn at cruise speed, neutral rudder.
    a) If model drops nose first → nose heavy
    b) If model drops tail first → tail heavy
    c) If model drops approximately level, balance is close

- CG location refinement & optimization
  - Advanced flight tests for CG involve advanced aerobatic maneuvers e.g. long downlines, Knife Edge flight, snaps & spins; for 3D - use stalled flight maneuvers (e.g. hovers, harriers, flatspins.)
  - Ultimate CG determination is an iterative process of testing and personal preferences.
  - Some fliers use 2 different CG locations, one for aerobatic flight, and a more rearward CG for 3D flight.

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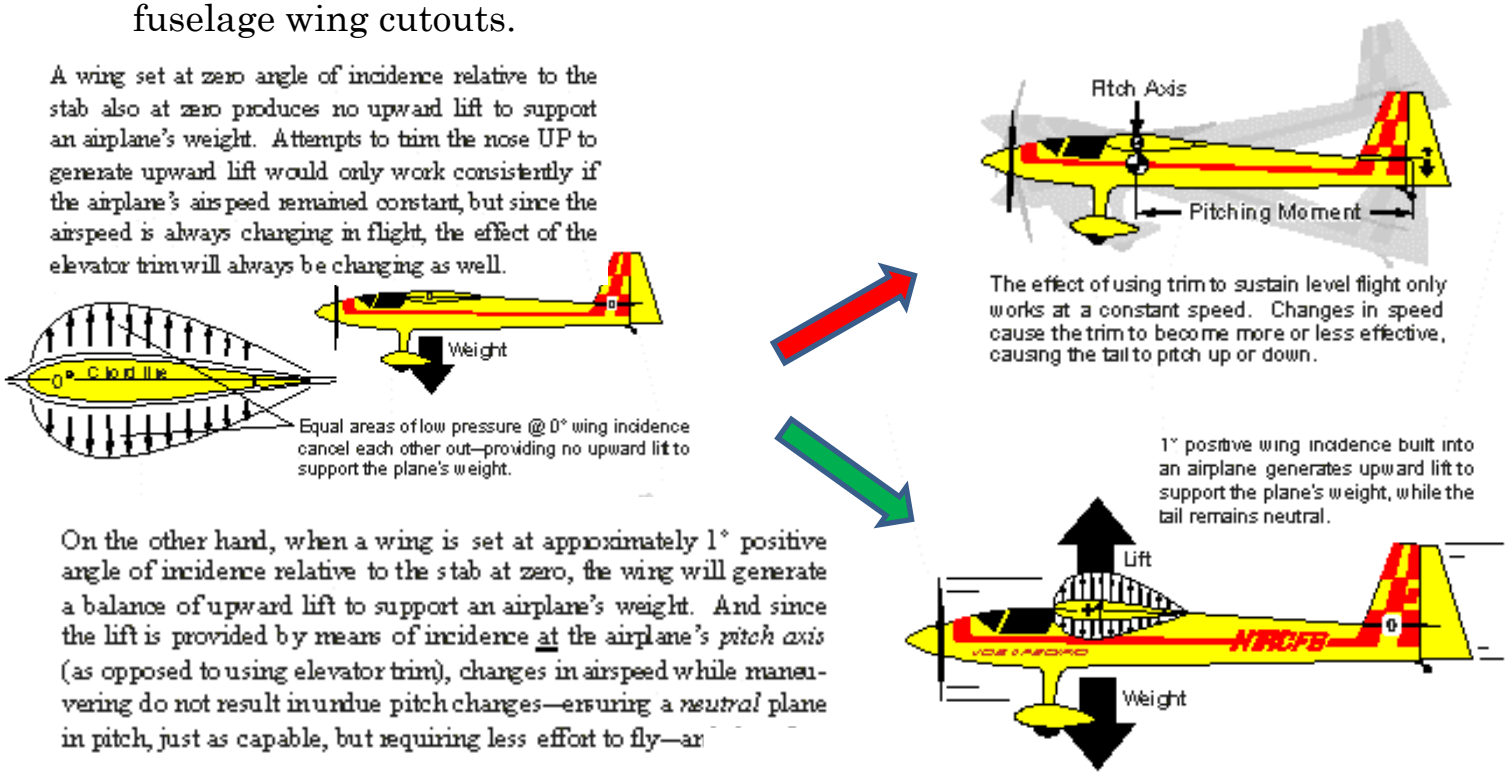
Wing Incidence Settings

- Lift vs. Angle of Attack (see David Scott of **"1st US Flight School "** pic source)
  - "Angle of attack" is wing angle relative to airflow using "zero lift" line as reference
  - KEY - All airfoils need a positive angle of attack (measured from ZLL) to produce lift
  - Angle of attack achieved one of two ways:
    - Wing/stab at 0/0. Thus elevator "+" trim necessary – plane is pitched nose up to achieve sufficient pos. angle of attack
    - Positive wing incidence - 1/2 degree to 1 degree, horizontal stab at 0 (neutral)
  - Significant number of ARFs designed with 0 wing incidence & 0 stab incidence.
  - Fly & try. If negatively stable, consider adjusting wing incidence via shims or redoing fuselage wing cutouts.



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Control Surfaces

- **Control Surface - Throws vs. Size**
  - Throws - Use manufacturer recommendations & OFK inputs
  - Larger control surfaces need smaller throws for precision flight.
  - Start with low throws and increase after initial flights
  - Caution: Large aileron throws especially with large ailerons → crash waiting to happen
- **Hinges:** Hinge lines - straight and centered on the surface
- **Pivot Point of Control Horns:** Control horns setup with pivot point of horn exactly on the hinge line to avoid accidentally building in a differential.
- **Servo Arms:** The arm on the servo should be exactly parallel to the hinge line. Servo arms should be switched around until you get the spline alignment correct.
- **Servos:** Select quality servos of sufficient torque. Test & match for best setups. Centering is critical.
- **Subtrims are for fine tuning only**. Do NOT use the radio "sub trims" or fine tuning to center the servos more than a couple of degrees !!!
- **Hinge lines** should be **sealed** so no air can pass through.
- **Eliminate slop & "play".** Minimize pushrod slop. Do not oversize holes. Use high quality ball link attachments and machined aluminum servo arms for the best setups.
- **Aileron & Elevator Setup** - Mechanically adjust linkages so that ailerons & elevators are perfectly centered and get only the maximum throw recommended by the manufacturer. Equal up and down.
- **Rudder setup** – Achieve maximum available throw for rudder. Secure mechanical advantage to ensure good resolution and power

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Engine Thrustline Settings

- Thrustline - typically need slight down-thrust and right-thrust
  - Issues appear most often in high power but low speed flight situations
    - Takeoffs, stall turns, tops of loops & Immelmann's, Cuban Turnaround Uplines
    - Caused by combination of slipstream & P factor effects
    - Sometimes excess wing incidence (down-thrust correction) at high speeds

- Initial Thrustline settings
  - Use manufacturer's suggested settings
  - OPK inputs with large degree of caution & discretion.
  - Default – Right-thrust 1 to 2 degrees, down-thrust 1 to 2 degrees then test.

- Flight Testing Thrustline settings – Thrust controls uplines
  - Do after CG is established as "close" & wing incidences are set "close"
  - Initial flights good to do without cowl till settings verified. Access & adjustment issue.
  - Wings level, moderate speed directly into wind, pull up hold power. Observe changes as plane slows toward top half of upline. Repeat with the wind.
    - Plane tucks to belly, → reduce down-thrust
    - Plane pulls to canopy → increase down-thrust
    - Plane pulls to left → increase right-thrust, also possible down-thrust increase
    - Plane pulls to right → reduce right thrust
    - Results may change if props are changed. Retest & verify.
  - Large down & right thrustlines settings different from 1,1 or 2,2 degrees→ may indicate other issues. Retest & verify, recheck for other causes - e.g. incidences.
    - High speed straight level flight directly into wind – quickly cut throttle. Observe plane.
    - Significant flightpath changes may indicate "other" issues. Iterate other trimming steps & tests.

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Computer Radio Capabilities

- Dual Rates
  - USE dual rates.
  - Primary flying on low rates for precision
  - 3D maneuvers, possibly snaps & flatspins on higher rates.
  - High rate ailerons can quickly get you into trouble
- Exponential
  - Use judiciously
  - Low rates – small % EXPO. Must still feel the controls for smoothness
  - High rates – Larger % EXPO stops unwanted jerky movements
  - EXPO is NOT a substitute for precise stick movement & control
  - High rates + large % EXPO does not always make a smooth flier
- Mixes
  - Use to coordinate dual surfaces (slave) from one input (split elevators)
  - Use to correct unwanted flight & coupling issues if mechanical or aerodynamic changes not viable .(Mix out problems.)
  - Caution - Can cause unintended & unforeseen effects & consequences

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- **Flight Testing from Maiden Flight**

Maiden Flight

(…hope the plane don't crash…)

- Ground check of controls & engine throttle.
- Takeoff & attain altitude
- Adjust Xmitter trims for straight & level flight.
  - Ailerons first. If OK proceed.
  - Elevator next If OK, proceed.
  - Vary throttle, does plane climb & dive ? If OK, proceed.
- Low rates – are throws are sufficient, but not too much ? If OK, proceed.
  - Rudder trim adjusting –
    - Straight into wind, wings perfectly level, good speed, pull vertical & observe.
    - Fly with tailwind, wings perfectly level, high speed, pull vertical & observe.
    - Repeat to verify. Any heading change or roll at outset ? Trim rudder correction.
    - Optional - Loop straight into wind, wings level, see if corkscrewed. Trim rudder correction .
  - CG flight tests 1 & 2 (previously covered). Consistent results ?
- Land & adjust
  - Measure deflections set & record.
  - Adjust trims mechanically (or with subtrims if deflections are small) to achieve same deflections recorded but w/ neutral trims
  - Fly and verify trim settings.
  - Adjust CG as necessary from tests. Test fly for results.
  - Readjust & test fly.
  - Test other parameters in flight. One change at a time. Test fly for results.
  - Iterate process