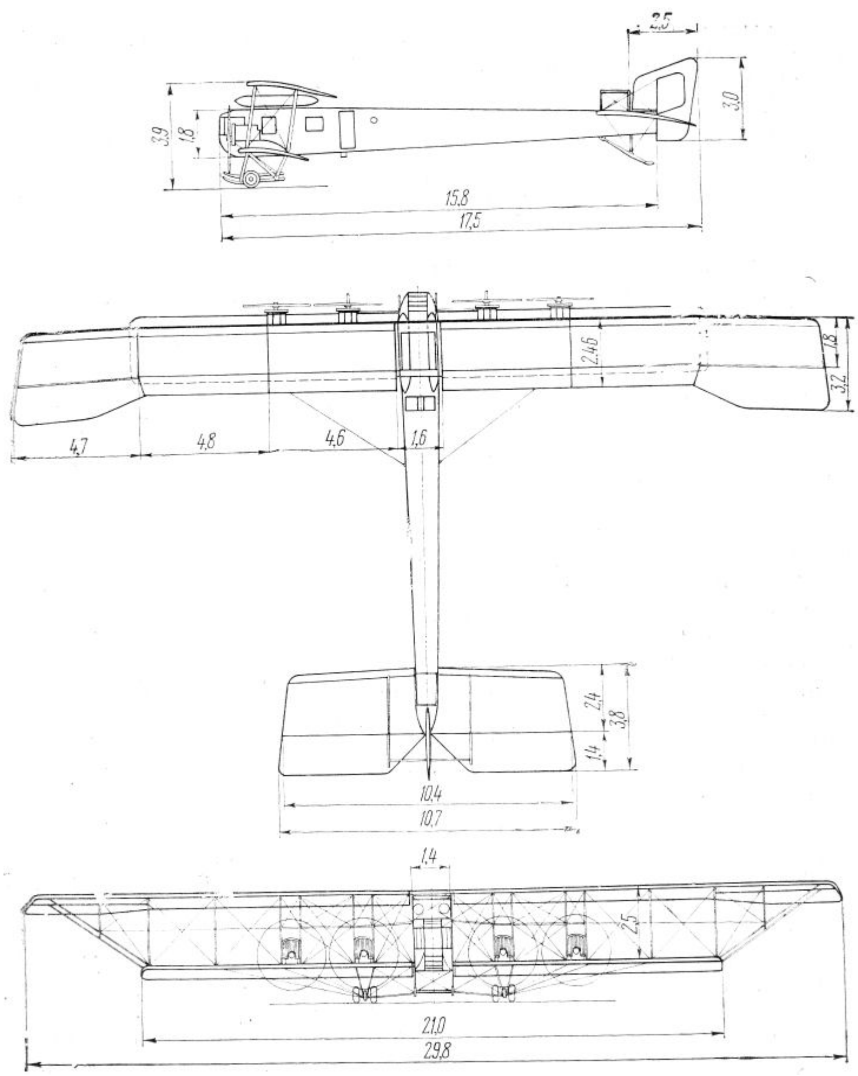
Four-engine WWI bomber for REFLEX XTR²

Sikorsky Ilya Muromets S-23

A simulator model used to explore possible flight characteristics

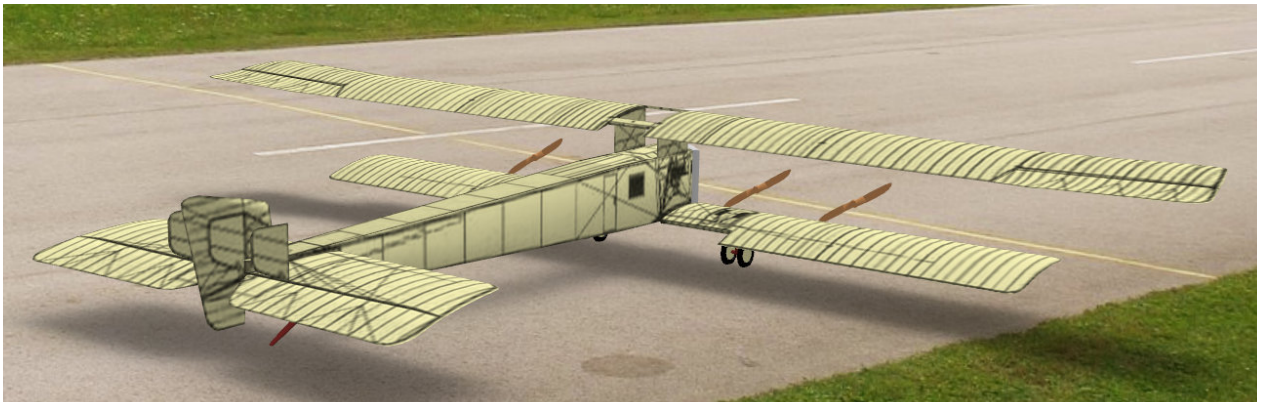
A huge 1:6 model of this very special aircraft (see at Wikipedia) was being built by *Salvatore Calvagna* (Sal) in 2015. To clear up some uncertainties about the airplane's trim or balance, respectively, he started a thread in the Aerodynamics forum at RC Universe. The discussion there finally led to me creating a crude simulator model of the real model being built, just to try it out in a crash-proof environment (HD video of a demo flight at YouTube).

A three-view drawing provided by Sal:



The REFLEX simulator model

The word crude means that the simulator model's appearance has been done "quick and dirty" just to have the correct sizes and positions of wings, tail, propellers, and landing gear. All unnecessary details have been omitted:



To have the correct impression of the model's attitude in flight was intended as well:

To achieve that, the physics parameters rendering the flight characteristics had to be meticulously calculated (not crude). Now that was needed anyway for the project's main goal: anticipating the model's flight characteristics.

There are three parameter sets (model versions) differing only in balance and correspondingly in horizontal stabilizer incidence:

Ilya Muromets **unstable**:
The C/G is close to the wings' trailing edge, *behind* the neutral point, making for about -14% (negative!) static stability margin. That means an unstable balance, but the airplane is balanced nonetheless. It just tends to diverge from a flight path by pitching up or down, even if only gradually because its pitch damping is huge. This is what we were afraid of as a worst case and the actual reason why the simulator model was built.

Ilya Muromets **neutral**:
The C/G is *at* the neutral point, making for zero static stability margin. That means a neutral balance and the airplane has no tendency to increase or decrease its pitch, it's just indifferent. This seemed to be worth striving for by putting as much weight as possible forward in the model. The simulation showed how much it would be worth.

Ilya Muromets **stable**:
The C/G is *ahead* of the neutral point, making for about 8% (positive) static stability margin. That means a good stable balance and the airplane tends to return to a pitch attitude and flight path if disturbed, just gradually as well due to huge pitch damping. This had been seen as an optimistic case in the first place, but it's how the model turned out in the end.

All three parameter sets (model versions) have been adjusted after the real model had been flown. Wingspan is 16.3 ft, weight 50 lbs. There are four 4130/20 electric motors with 16x8" scimitar propellers and 6s LiPo batteries. Drive power has been estimated (calculated) for the nominal 3.7V cell voltage, which is reached when the battery has about 20% remaining charge. So this is a conservative estimate and real power should be higher.

The propellers' wash on the wing makes for a noticeable amount of additional lift (propulsive lift). Especially with more aft C/G, this let the simulator model rear up and go out of control. Because the effect's real magnitude was unknown in the first place, it had been set to zero on the simulator model. Now a mild effect of propwash is set so the airplane tends to climb steeply but is still controllable by some down elevator, even the unstable version.

The real model's horizontal stabilizer is fixed at the prototypical angle of incidence. The model is trimmed for its C/G position by an appropriate amount of down elevator. The simulator model versions are trimmed for their respective C/G positions by setting the horizontal stabilizer to higher-than-prototypical incidence angles, more for the unstable version and less for the stable one.

Flying the Simulator Model

The thin and highly cambered airfoil makes for a violent stall. The standard recovery procedure is appropriate but still requires some altitude. The airplane has to be kept going when it's close to the ground to avoid any stall.

The *unstable* trim lets the airplane raise its nose when it gets slower – a self-enforcing process. When it gets faster it lowers its nose – a self-enforcing process as well. While the former leads to a stall at a certain low speed, the latter leads to "tucking-under", that is an automatic dive at a certain high speed. The unstable trim makes the airplane's speed range (between those two speeds) rather small so the pilot has to be in control all the time.

Working the throttle (ESC) is needed to stay in the small speed range. Even a landing approach requires still decent power. Flying a turn requires a lot of power, so commencing a somewhat steeper turn should be accompanied by setting full power at the same time, just to be safe.

Due to the highly cambered airfoil, there is inevitably a lot of adverse yaw. It must be canceled out by rudder to make the airplane turn at all. An aileron-to-rudder (combi) mixer in the transmitter comes in handy, set to 50% mixing rate (half rudder with full aileron).

Again due to the highly cambered airfoil, and due to the big wingspan as well, the ailerons are moderately effective. Then again, a lot of top aileron is needed. It's not possible to do that with a mixer, only a gyro in the airplane could do it automatically. Anyway, bank angles greater than 45° should be avoided lest the airplane gets out of control.

The pitching-up effect of propulsive lift is biggest on the unstable version but it is noticeable in all versions. It is easily compensated by a small amount of down-elevator proportional to power setting. A power-to-elevator mixer in the transmitter comes in handy, with about 10% set for the unstable version and 5% for the stable version.

All three versions of the simulator model are well set-up. They are trimmed for their respective C/G position, have suitable control throws (the airplane is not sensitive here), and show a moderate amount of pitch-up by propulsive lift. In case you want to feel like the test pilot of an unruly prototype, that could be adjusted in the simulation parameters as well. Questions about how that could be done are welcome.

Demonstration Flight

The demo flight (HD video at YouTube) is found in the simulator by pressing F9 and then selecting “Ilya Muromets” in the lower list titled “Aircraft”. If “Radio display” is checked in the “Radio” menu, a radio with telemetry is shown displaying values like speed, climb rate, and more.

In a dive following the turn after take-off, the onset of “tuck-under” is shown, noticeable by a few pitch oscillations. Then, the typical tail-high attitude in level flight is shown, followed by several typical stalls with recovery. Three landings show that a stall occurs only in a nose-high/tail-down attitude and that there is no porpoising after a three-point or a wheel landing.

About the Simulator

The REFLEX XTR² model flight simulator (that’s the official name) is available in a modern version that is particularly interesting for its multicopter (drone) simulation. It comes with all modern EPP models made by Multiplex and airplane physics is improved for new versions if need be, so the Ilya Muromets model flies pretty realistically. Customary (game-controller compatible) USB simulator interfaces (with cable or wireless) can be used to connect your actual transmitter; the special interface is no longer needed (but still works). So just the software (for MS Windows only) is easily available for download in a web shop, even as a free trial version.

Some information about the simulator is in my personal review web page, and several simulator versions of vintage and modern models are available on my download page. The Ilya Muromets simulator model is here. Hints for installing models in the simulator are at the top of the download page.

Calculations

The values used for aerodynamics calculations in *Blaine Beron-Rawdon’s* Plane Geometry spreadsheets are available for download at my download page (last item in this section) or directly here. The complete electric drive calculation spreadsheets are available for download here.

Enjoy!

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