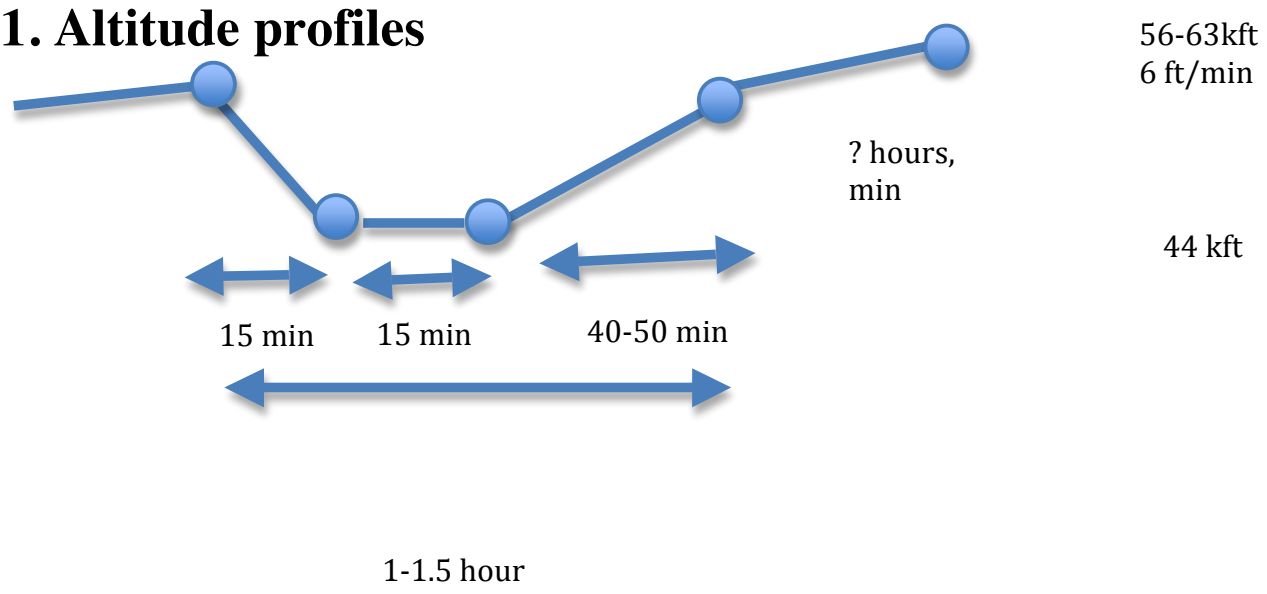
Flight planning discussion-Brian Toon, Lenny Pfister, Leslie Lait

Major issues

1. Altitude profiles



2. Fuel freezing

3. LostLink

4. Downlink bandwidth

1) Instrument constraints/desires

c) Altitude profiles-

i) cruise climb and descent-ascent/descent rates?

Cruise climb: A sample flight I worked up (with no dives) goes from 56 kft at 1.24 hrs since takeoff, to 63.47 kft at 22.74 hrs since takeoff. This is a climb rate of about 5.8 ft/min. (But note that on the GloPac arctic flight, with warmer temperatures, the climb rate was much lower.)

Descent rate: The GH does not descend at a uniform rate, but goes faster and slower according to some internal logic of its onboard computer. I examined several Vertical Profile Maneuvers (VPMs) during GloPac that went to 13.1 km (FL430) from around 17.3 to 17.8 km. (These were during actual flights, not from the flight planner). The descent rate **averaged** around 1000 to 1300 ft/min. But in the steepest portions (which being the steepest covered much of the altitude range), the rate got up to around twice that.

Ascent rate: The GH takes a lot longer to ascend than the ER-2 or the WB-57. Think in terms of a slow asymptotic approach to the max alt. The GloPac VPM ascents that I looked at from GloPac recovered their pre-VPM altitudes after about 40-50 minutes (that's ascent time only, not the whole maneuver).

ii)stair steps?

The GH cannot be commanded to fly at specific altitudes between 45 kft and 60 kft. It can cruise climb up or descend down through that altitude range, but it cannot fly at, say, FL490. Thus, the level portion of each step much avoid this range.

iii) stacked legs?

Should be the same as for stair steps.

iv) constant P, constant potential temperature, constant ozone?

Constant P is constant (pressure) altitude, of course, so that is OK aside from the 45-60 kft exclusion. Flying along other surfaces would require continual intervention by the pilot. Remember: the aircraft flies itself; the pilot merely overrides the pre-loaded flight plan with new instructions. This is fly-by-mouse-and-keyboard, not fly-by-joystick. That is, the frequent small analog adjustments a pilot might comfortably make in the cockpit to fly along a surface may be more onerous in the GHOC. There would also be constant instructions from the back room (where the latest numbers for ozone and potential temperatures would be received) funneled through the Payload Manager into the front room. Coordinating these communications may be a little tricky. Still, these issues might be worked out with the pilots; I'm just saying that it's going to be more difficult than in other aircraft.

v) Max altitude spiral descent to land, take off?
Cruise climb in and out of airport?

I suspect that the preferred procedure will be to spiral up for a bit, giving us a chance to check that all systems are operational, and then climb out to some defined point. During GloPac, this point was called "LOSTLINK" because that is where the aircraft was programmed to return if it lost communications with the GHOC. Keeping this point the same from flight to flight simplified things: everything from takeoff to LOSTLINK, and from LOSTLINK to landing, was kept pretty consistent, helps with interactions with air traffic control. The science portions of all flights began and ended at LOSTLINK. (That is, the instruments were mostly running before and after LOSTLINK, but the path was fixed and not influenced by science requirements.) The aircraft would be at max altitude at this point, around 56 kft after takeoff and 62 to 65 kft on return.

I anticipate that there will be corresponding LOSTLINK-type points defined off the coasts of Guam, and Darwin. If so, then plan on about 1.5 to 2 hours from takeoff to the LOSTLINK-equivalent, and about the same from LOSTLINK to landing. This leaves 29 – 4 = 25 hours for science-directed flight paths.

d) Targets of opportunity-what triggers do we use?

i) cirrus from lidar

ii) predicted inflow or outflow regions from convection?

iii) along temperature gradients?

iv) along ozone gradients

v) Kelvin waves, what does flight plan look like?

vi) What does flight plan for small scale waves look like?

2) Aircraft constraints (GH and G-5)

c) Flight duration-

i) straight-line flight out of Guam, cruising-climbing at altitude all the way out and back. This gives us: Flight time: 28:4 Total distance: 9499 nmi. Fuel consumed: 13,461 lbs

ii) a 2375 nmi segment (i.e., a quarter of the 9499 nmi above) down to flight level 490 (49,000 ft, or about 15km). Then the flight was shortened until the fuel consumption was OK; The result is: Flight time: 24:20 Total distance: 7713 nmi Fuel consumed: 13,483 lbs

iii) a 2375 nmi segment down to flight level 440 (44,000 ft, or about 13.4 km). Then the flight was shortened until the fuel consumption was OK. The result is: Flight time: 20:23; Total distance: 6206 nmi; Fuel consumed: 13,472 lbs.

iv) Doing a vertical profile maneuver (VPM) to FL440 with a 15-minute loiter time at the bottom will burn an amount of fuel and take an amount of time that depends on how early or late in the flight the VPM takes place. On average, such a VPM will cost roughly extra 280 lbs of fuel (give or take about 50 lbs). As a rule of thumb, given roughly 500 lbs/hr fuel consumption, each such VPM can be expected take about a half-hour away from the flight. The duration of the VPM will be between 1 and 1.5 hours from initial descent to the end of the

ascent.

d) Flight turnaround time

See d.

e) Flight hours available

Proposal says that each campaign (excluding test) will have 200 flight hours and 8 science flights. I assume that the transit flights are included. That means 6 flights in about 5 weeks. Though we did not get this during GLOPAC, we have been assured by Dave Fratello during telecons that the GLOPAC pace will be improved upon. I remember Dave Fahey saying at the beginning of GLOPAC that we might manage 3 flights every two weeks. This is consistent with the above pace.

f) Crew rest limits

From my (Lait's) GloPac notes on discussions with the pilots: 14 hrs max crew day (includes 2 hrs pre-takeoff, 1 hr post-takeoff). This is followed by a min 12-hr off-duty period (including 8 hours uninterrupted rest). Two pilots required on-station for takeoff and landing; otherwise, one pilot can take a 1-2 hr break. One-hour overlap between rotating crews: if crew #2 comes in at 1400, crew #1 leaves at 1500.

We need to think about science team rest as well. Don't know the answer to this, but need to know to see about things like "back-to-back."

g) Altitude-max

Absolute max altitude is 65 kft (19.8 km) at the end of the longest (29-hr) flights.

But this varies with temperature. It is high when temperatures are cold. In the arctic flight, with warm temperatures, we got to 17.7 km pressure altitude near the pole (with the warmest temperatures – this was half way through the flight, about 14 hours). At the end of the flight, over Dryden, we got to 19.6 km pressure altitude. Fuel load at the pole was greater than at the end of the flight, and this affects things as well. On the flight where we got into the tropics, at 14 hours we were at 18.8 km (We might have had less fuel on this flight).

h) Climb and descent rates

Descent rate is about 1300 feet per minute. Stepwise is possible.

Ascent rate is slower, becoming slower as previous cruise altitude is approached. Would estimate about 500 feet per minute.

i) Interaction with convection

No thunderstorms within 25 nautical miles. No convective cloud tops higher than 50Kft within 25 nautical miles. These things are evolving, and are not sacred scripture.

j) Lidar interactions with G-5.

k) Altitude separation with G-5

j) Instrument intercomparisons with G-5, space and time separationlanding limitations-cross wind, rain on runway, nearby clouds

k) Landing limitations-water on runway, nearby convection, cross wind

l) Coordinating with aviation authorities:A number of areas (the region surrounding Hawaii, for example) will want advance notice of 7 business days (not calendar days) if we intend to fly in their airspace. Our main area during GloPac, the Oakland Oceanic FIR, wanted advance notice of 3 business days. Expect similar requirements for the various foreign FIRs.

m) Air temperature limits: Global Hawk has

problems with low air temperature. Possible big problem for our goals.

n) Three kinds of flight plans

We should probably be thinking in terms three (or maybe 2.5) types of flight plans: (1) the plan to be loaded into the aircraft computer, (2) the plan to be filed with the aviation authorities, and (2.5) the plan that is actually flown. Your science planning and discussions will rightly be focused on (2) and the real-time modifications that give us (2.5). The important thing to recognize is that (1) is a very different kind of animal from the others and will require special effort. This is the flight path that the plane will follow if it is left purely to its own devices. After reaching the LOSTLINK-type point, the pilot will issue instructions to the GH computer to override the type-(1) plan and follow the filed type-(2) plan instead. This is done step by step during flight, and if at any point we lose communications with the GH for more than 40 minutes, the aircraft will rejoin the type-(1) path (what they call the "black-line path") and proceed back to the landing site. At every point along that black-line path, contingencies are programmed in to address what the GH should do if it loses communications, loses its engine, etc. For our flights over the ocean, most contingencies are simple: crash into the ocean. But for climbing out and landing, the path (and the contingencies) must be carefully laid out in exact detail to avoid populated areas. Thus, while flight plan types (2) and (2.5) are similar to what we have

done with other aircraft in the past, this type (1) plan is much more complicated for flight ops. And before they can be loaded into the aircraft, all our type (1) plans need to be submitted to Northrop-Grumman to be run through their simulator. As a civilian science mission, ATTREX would have a lower priority than the many Air Force missions, so it can take a while to work our way up the queue. It can take months, so the earlier we get started the better. Basically, you want to distill from the science flights a few basic patterns or envelopes, such that if the aircraft loses communications while following the filed type-(2) flight plan it can join the type-(1) path and continue on home without crossing over a half-dozen unfriendly countries and without running out of fuel. The basic flight paths from the proposal (FP1 through FP4) for each operational area can serve as a starting point.

3) Coordination with G-5
   c) Does G-5 only fly with GH?
   d) Can we do back to back with G-5 (G-5 out 4 hours with GH return, rest 8 hours, out 4 hours to meet GH).
   e) How many flights per week can G-5 do?