LAIMA: THE FIRST ATLANTIC CROSSING BY UNMANNED AIRCRAFT

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Ron Bennett photo

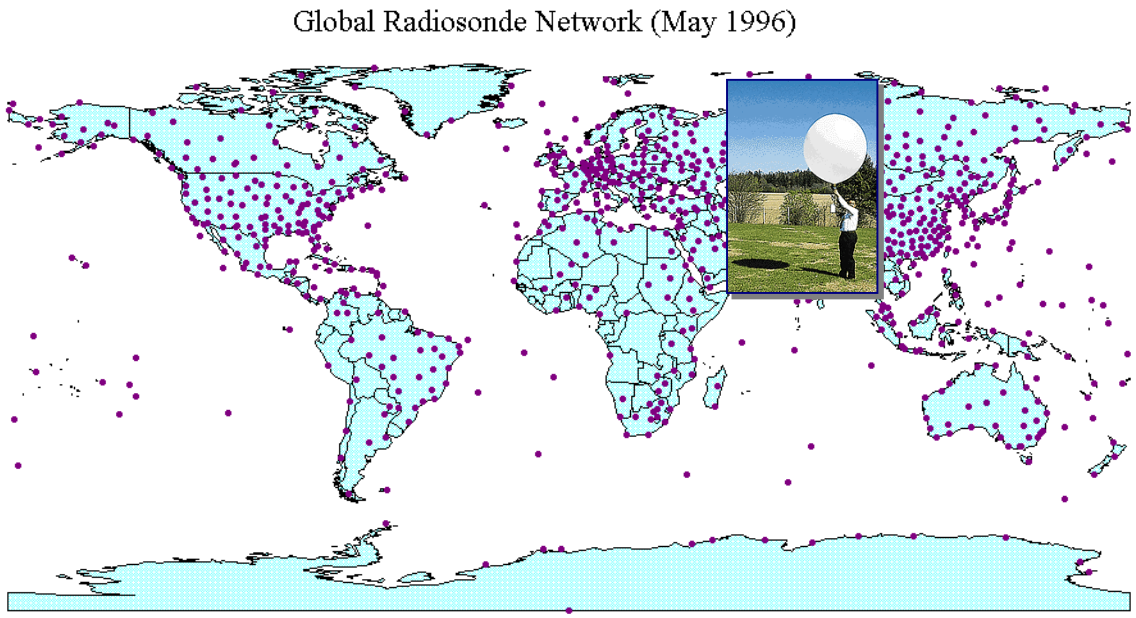
Aerosonde *Laima* lifts out of her cartop launch cradle on Bell Island, Newfoundland, 7:29 local time on 20 August 1998. She flew east through a stormy night, out of touch with the ground but shepherded by her namesake, the ancient Latvian deity of good fortune. After 26 hr 45 min she plopped down in a meadow on South Uist, off the Scottish coast, and so became the first unmanned aircraft - and, at only 13 kg gross weight, by far the smallest aircraft - ever to have crossed the Atlantic.

Newton's concept of gravity, it is said, was born under an apple tree. On the scale of history, the idea for the first robotic flight across the Atlantic must admittedly be assigned a rather lower rank, but at least it had a similar provenance. It came to mind one winter's evening amidst the sleeping orchards of the Hood River valley. I had dined with my old classmate Andy von Flotow, and being, it must be acknowledged, irremediable nerds, we talked as always about engineering. I had just returned from Western Australia, where a trial was then underway of the *Aerosonde*: a miniature weather-reconnaissance aircraft on which, by then, I had been working for six years. This trial was the most ambitious since my group's start of field work in 1995, particularly in our use of multiple communications sites to extend the domain of operations along the "cyclone alley" coast of the desolate northwestern Pilbara. But even so we could monitor

aircraft over only a couple of hundred kilometres of coastline, and only a hundred or so out to sea - far short of the Aerosonde's long range, and of the over-the-horizon reach needed to realise our ultimate goal of routine reconnaissance in the open ocean. To go further we awaited (and still await) new satellite-telephone systems, which were then more than a year away from service. However Andy, characteristically undaunted and with globe in hand, pressed me about ocean crossings. He eyed the North Atlantic: "Maybe it's time for a stunt."

We joked about possibilities, but I, for my part, didn't take the idea very seriously. Not that it wasn't technically feasible: Newfoundland to Ireland, the obvious route for a transatlantic demonstration, was certainly within an Aerosonde's range. Moreover we didn't actually *need* the enroute communications for which we had been waiting. In a pinch, faith, hope, and charity could serve instead: we would simply dispatch an Aerosonde from Newfoundland along a stored transatlantic route, and wait, however uncomfortably, for it to materialise at the other side.

So it *could* be done, at least in principle. Whether it *should* be done was another question. Should we put our effort into yet more field work, which had already taken a great deal of our energy for many months, or instead into engineering, which had consequently suffered from neglect? We had been improvising answers to this question for years, and making the right choice was becoming acutely important.



Laima owed her development to a chronic problem in meteorology. Balloon soundings of the atmosphere, made twice daily at about 1000 sites worldwide, supply the lifeblood of computational weather forecasting. However soundings over the ocean can at present only be taken by launching instruments from ships or aircraft, which are too expensive to operate in any numbers. Miniature Aerosondes like *Laima* promise to make oceanic data collection affordable on a much larger scale.

The Aerosonde Concept

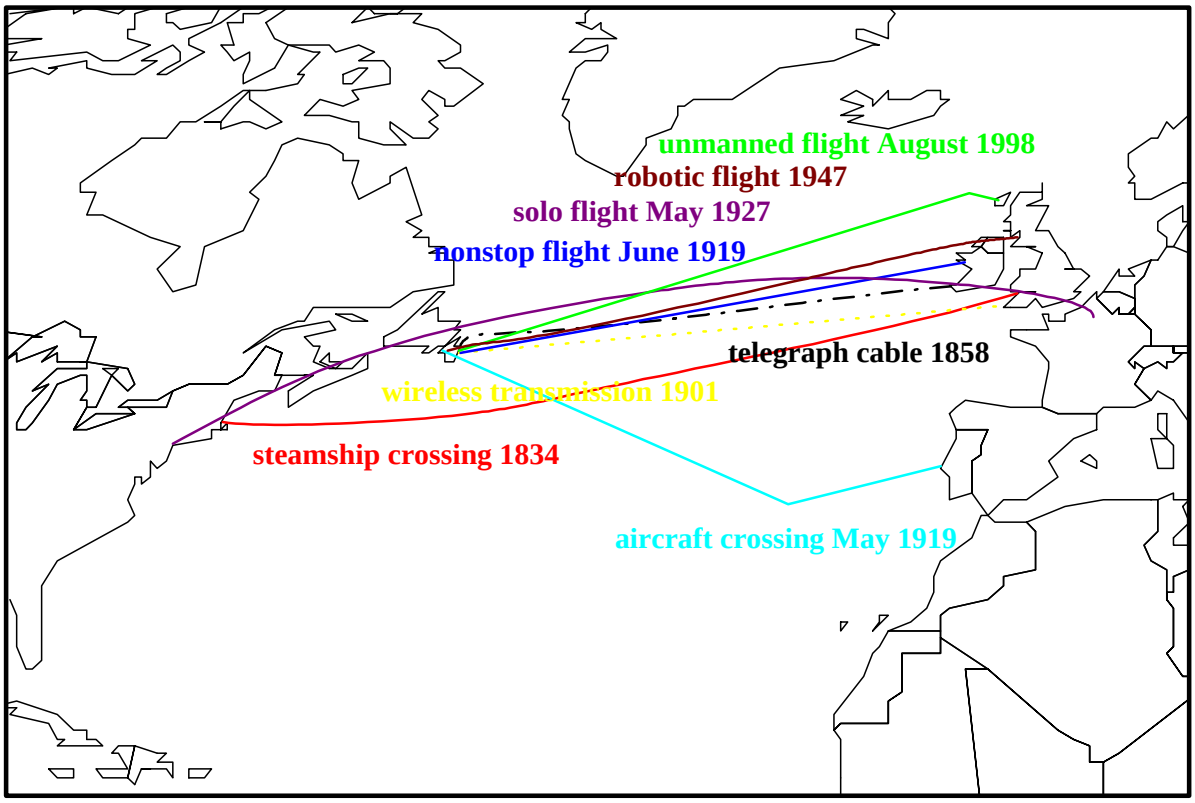
The Aerosonde idea began in 1991, as a response to the chronic shortage of weather data over the oceans. Although satellites generate much useful information, forecasters and their numerical models depend crucially on data which satellites cannot supply: *soundings* of temperature, pressure, humidity, and wind from the surface to high altitude. To take soundings, meteorologists use balloon-borne *radiosondes* or parachute-borne *dropsondes*. The sondes themselves are light and cheap - costing less than US$100, and weighing only tens of grams - but the ships and aircraft needed to launch them at sea are large and very expensive. Consequently weather services cannot afford to gather much data offshore.

In 1991 it occurred to me that, in view of miniaturisation of the necessary components (including especially the then-new receivers for the Global Positioning System) it would be feasible to design a miniature long-range aircraft which would itself be the sounding instrument. Such an *Aerosonde* might be no more expensive than a balloon on a cost-per-sounding basis, but it would be able to reach almost anywhere over the oceans or remote lands areas. A substantial improvement in global weather forecasting would then be within reach. The idea was picked up with particular enthusiasm by Greg Holland of the Australian Bureau of Meteorology, and by Robert Abbey of the US Office of Naval Research. Together we began, slowly at first, to develop the concept and a philosophy of development.

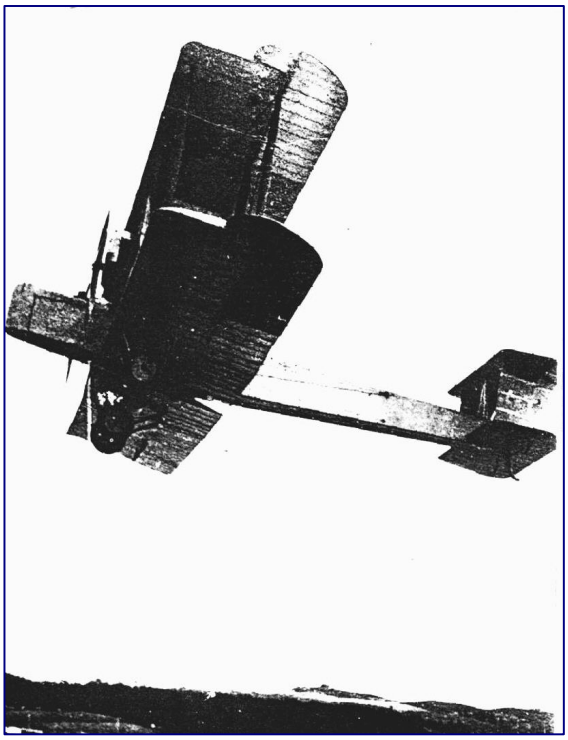
From the start it was fairly obvious that sufficient engineering effort would yield a suitable aircraft. However a bigger uncertainty surrounded how the aircraft might be used. This made our job a bit different than that of, say, Boeing or Airbus in developing a new airliner. For an airliner, the "system-for-use" - airlines, passengers, airports, regulatory standards, air-traffic control, *etc.* - is well established, and the economics are well understood. Consequently the development effort can concentrate on engineering, and routine service can begin as soon as engineering is complete. But for Aerosondes the only thing well-established was the need. Beyond that, the idea of routine long-distance operations by tiny autonomous aircraft was entirely novel, and raised all kinds of new issues. How could an aircraft without a pilot avoid other traffic? How might regulations restrict where and how they could fly? What would their operating costs be in practice? Would weather services fund them? What routes would be best? To address these questions, we saw that the aircraft and the system-for-use would have to be developed *in parallel*. This called for a series of field trials expanding gradually in scope toward routine operations.

That philosophy - and limits on our funding - dictated the approach taken when my company, The Insitu Group, was incorporated in mid-1994. We had a short-term focus: to produce prototype aircraft for initial trials off northern Australia at the end of 1995. That we did, and so set off, with only a handful of flight-test hours under our belts, to grapple in the steaming tropical bush with some of the most powerful thunderstorms on the planet. We managed to cope well enough to boost interest among prospective users, not to mention our own confidence. But while the “gee-whiz” elements - tiny fuel consumption, autonomous operation, penetration of rough weather, and so on - worked well the first time out, a lot of basic engineering was left to be done on reliability, particularly of the engine and fuel system.

By that winter's night in Hood River, thinking about the Atlantic, we could look back on two years of further results: demonstrations around the Pacific with some 20-odd aircraft; several flights exceeding 24 hours; more encounters with thunderstorms and rough weather. Reliability was better as well, but still not very good; aircraft in the field were requiring far too much support and suffering far too much attrition. This was due at least in part to ongoing trials taking time from engineering, which was a something of a vicious circle inasmuch as, without reliable aircraft, demonstrations were that much harder to mount, and so left even less time for us to make the aircraft better. Having just returned from yet more first-hand experience of this problem in Western Australia, nobody in my Group was particularly enthusiastic about a new transatlantic effort.



Crossing the Atlantic has had a special cachet for centuries. The first steam crossing in the 1830s, the first Atlantic cable in 1858, and the first radio transmission in 1901 were all recognised as key milestones in technological advance. The first aircraft crossings, following on progress made during the first world war, generated great excitement about the potential of aviation. Lindbergh's solo flight in 1927 set a further milestone in range and reliability, and within a decade transatlantic flight had become routine. 1947 saw the first "robotic" flight, in which the crew of a special US Air Force C-54 refrained from touching the primary flight controls all the way from start in Stephenville to stop in Prestwick. It took another 51 years for the robot to throw out the transatlantic crew!



Inching skyward with an overload of fuel, John Alcock and Arthur Brown nurse their Vickers *Vimy* away from St John's on the afternoon of 14 June 1919. The next morning, after more than 16 hours flying with harrowing escapes from fog and icing, and blocked by bad weather to the east, they landed in a bog on the Irish coast. They had made the first nonstop flight across the Atlantic, won L10,000 from the London *Daily Mail*, and opened new frontiers in aviation.

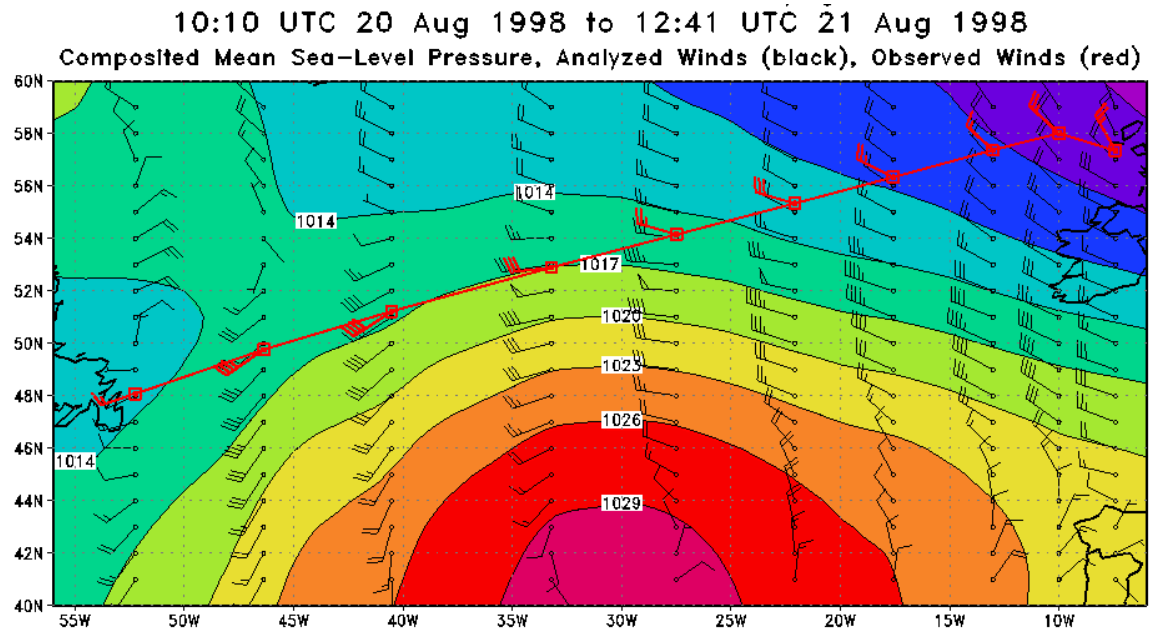
The siren song

On the other hand, while our field exercises had gone some way toward generating interest in the Aerosonde, awareness was still limited mainly to small groups of meteorologists and people in aviation. So all of the reasons for doing demonstration flights still applied, and to an Atlantic crossing they applied in spades. To link the Old World and the New, to cross the Ocean steeped in its legacy of the Vikings, Brunel, and Lindbergh: *that* would raise awareness like nothing else could possibly do. And not least among our own group of engineers. I already knew, as well as anyone, what these aircraft could do, yet I was quite taken aback by the thought of actually trying to cross an ocean. That attitude had to change if we were ever to reach the point of routine service.

Thinking this over for a few days, I came to think that, maybe, it was indeed time for a stunt. We discussed the idea at Insitu, and with our colleagues Juris Vagners at the University of Washington and Greg Holland in Australia. The consensus was that an Atlantic attempt might offer much to gain, and relatively little to lose: a few Aerosondes and our time against a potentially big boost for the miniature-aircraft concept. We decided to pencil it in for the summer, to be reviewed in light of (still more) field exercises upcoming off Vancouver Island and in the South China Sea. Meanwhile we agreed to keep the thing quiet to avoid raising expectations.

The pact of secrecy was put to the test a few weeks later. We had been working for some time with meteorologists in British Columbia and Washington state on concepts for Aerosonde reconnaissance in the northeast Pacific, and had convened a meeting at the University of Washington to consider options. As we discussed how to generate interest, Cliff Mass - a

meteorologist from UW who was later to do our transatlantic forecasting - proclaimed "*You need to do a demonstration! Something dramatic! Newfoundland to Ireland!*" Mert Horita of Environment Canada quickly joined the refrain. Juris Vagners and I mumbled something about giving it a bit of thought and steered conversation into less sensitive territory. But the value of a demonstration could hardly have been made more clear.



Aerosondes are slow, with a cruise speed of only 40 kt or so, and winds can therefore make a big difference in range. We were looking for tailwinds averaging about 15 kt to cross the Atlantic with a comfortable fuel reserve. For flight planning, the US National Weather Service provided us with wind estimates from its Aviation model; here these estimates are shown by black barbs. On the day of *Laima's* flight, the model was so accurate that arrival time in Scotland was within 3 minutes of estimate, and *Laima's* logged winds - in red - matched the estimates all the way across. If the situation were this good all the time then weather services wouldn't need Aerosondes at all! However we had been careful to choose our launch day, and our route, so that conditions would be very predictable.

On we went through the spring, flying in rain and icing off the west coast, and in yet more thunderstorms and wilting humidity in the tropics. We chalked up 400 flight-hours in the first 5 months of the year, including 4 flights exceeding 24 hours - long enough, given favourable winds, to make the Irish coast. Pieces were still breaking far too often, and we had lost a few aircraft to one or another poorly-developed part failing or falling off. However the score was just good enough to make the Atlantic worth a shot.

The plan takes shape

So it was that early in May I started seriously to check feasibility. Weather was the first issue, since to make the flight with a comfortable fuel reserve we would need a healthy tailwind. Steve Lord, a computational meteorologist at the US National Centers for Environmental Prediction,

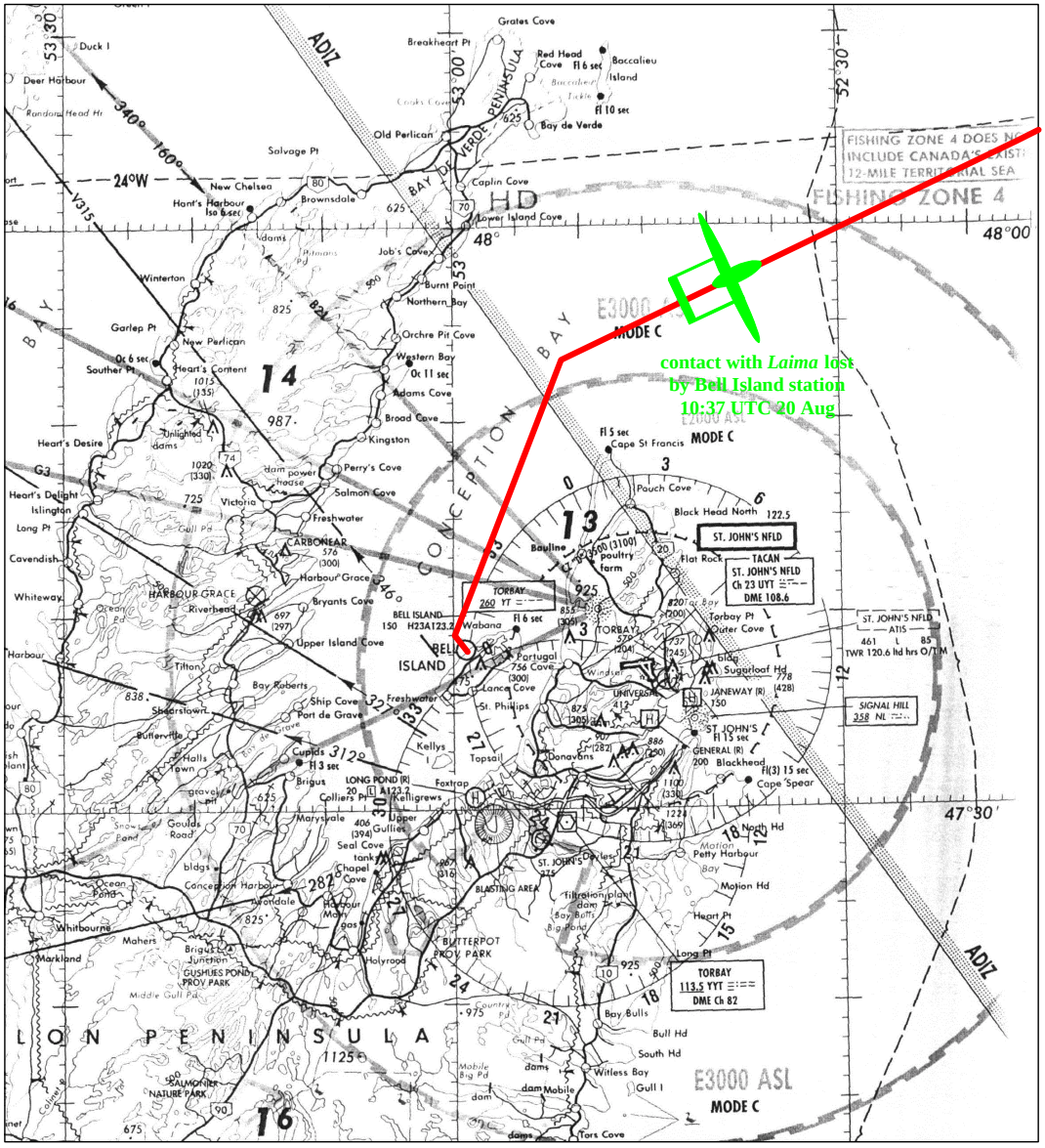
and an Aerosonde advocate of long standing, was let in on the Atlantic plan and soon looked up the climatology. The news, as expected, turned out to be good: average winds in July and August blow at about 15 kt straight from Newfoundland to Ireland. Cliff Mass, also now in-the-know, then checked further into several years' worth of records for altitudes around 5,000 and 10,000 ft. He came back full of enthusiasm about several opportunities per week with good winds below the freezing level (which we would not cross for fear of icing). Soon afterward, Steve arranged for wind excerpts from the US aviation-forecasting model to be posted regularly on the Web. These became vital for flight planning.

So the crossing would indeed be feasible. Would it be safe? One could think of various hazards: hitting another aircraft; hitting a ship if the aircraft went down; or hitting something on land if the aircraft went off course. We weren't concerned about the last problem: Aerosondes have range-safety provisions to cut the engine if they can't maintain track, and in any case we had never had an aircraft wander off course. For aircraft and ship collision, on the other hand, we couldn't do much better than random chance, which I estimated to be less than 1 in 100,000. In routine service we might be able to make the risk lower that that, but, as it was, we thought the number acceptably small for a one-off demonstration. Still, our opinion was neither here nor there; it was the opinion of the aviation regulators that mattered.

On the Canadian side, we had established good relations with regulatory and air-traffic services through our trials in British Columbia. We had been impressed by their handling of those programs, which was conscientious, critical, but at the same time positive and interested to find practical ways to accommodate this new-fangled gadget. They applied the same approach to the North Atlantic, and over the next couple of months we worked through the issues with David Wall of Transport Canada and with the staff of Gander oceanic control (which is responsible for the western half of the North Atlantic). The obligatory Special Flight Operations Certificate was issued in latter part of July.

On the other side of the Atlantic we had to start from scratch. Fortunately we soon made good contacts, notably with Mike Ankers at Prestwick Centre in Scotland (which handles the eastern half of the North Atlantic). Mike quickly understood exactly what we wanted to do, and asked a few very pointed questions about safety and position estimation. Once satisfied, however, he concluded that we could be handled without difficulty. We planned to use forecast winds to estimate position while enroute, and although the uncertainty band (based on possible wind error) would grow to perhaps 200 miles along-track at the end of the flight, a large box of "protected" airspace could be put around it. Both Prestwick and Gander agreed that such generous protection, while profligate, would not be a problem for a one-off exercise in view of the sparsity of low-altitude traffic over the sea.

That was fine until someone checked the rules: it turned out that international standards call for aircraft crossing the ocean in controlled airspace to make hourly position reports. But of course we couldn't supply anything but estimates - we were, after all, crossing on the faith-hope-and-charity plan. In the end this left no choice but to stay below the floor of controlled airspace at 5500 ft, and live with weaker tailwinds.



Aerosondes were launched from Bell Island in Conception Bay. *Trumper*, *Laima*, and *Millionaire* in turn flew down the Bay beneath the control zone for St John's airport, rounded Cape St Francis, and headed northeast for Scotland. Bell Island, now a slow-paced scion of a once-huge iron ore operation, proved to be a superlative base, not only because of its fine location and facilities, but above all because of the welcome and support given us by the cheerfully enthusiastic Islanders.

That, however, was only a minor inconvenience. Bigger problems loomed with the Irish Aviation Authority. Initial contact was made in May, and discussion proceeded fitfully as our proposal did the rounds of Aviation House in Dublin. As June and July wore on I had a number of encouraging conversations, but ultimately on 28 July - only a week before our planned departure - we received a fax advising that we must not enter Irish airspace. But in May that was all in the future.

After starting discussion with the air-traffic and regulatory authorities, I started looking for takeoff and landing sites. Our initial thought was to retrace the first nonstop flight by Alcock & Brown in 1919, from St John's to Clifden in Galway. However that plan was a non-starter; the launch site is now overrun with roads and buildings, and the landing site remains the same hill-ringed bog that nobbled their Vickers Vimy, nose-in-the-mud, in a comic finale to their triumphant achievement. We had to go elsewhere.

David Wall of Transport Canada suggested flying from Harbour Grace, west of St John's on Conception Bay. The disused strip there was actually built for Atlantic crossings, and made famous by Amelia Earhart in 1932. On receiving the topographical map, however, we saw that departure would take us first over some houses, and then down a narrow harbour for a couple of kilometres. That gave us pause: crossing 3000 km of open ocean might be safe enough, but we wanted to give built-up areas as wide a berth as possible. So out came the local aviation chart, and a ready alternative presented itself in the form of the airport on Bell Island. (Although we didn't actually need an airport, they are much easier than roads or meadows to assess from the end of a telephone line.) A check of documents and a chat with the local mayor made it clear that this was the ideal spot: on a cliff hard by the sea, looking down Conception Bay into the Atlantic, and with an nice building adjacent for aircraft and gear. It did indeed turn out to be a superb site, and made all the more so by the warm welcome and wonderful hospitality given us by the Bell Islanders.

For landing, a search of the Web turned up the informative Irish Aviation page. This gave us contacts for all of the airports on the west coast, and after many messages and phone calls back and forth we converged by mid-June on Belmullet in County Mayo.

Crossing the easy way

Any sort of novel flying with unmanned aircraft is best preceded by simulation, including "hardware-in-loop" simulation where, in effect, the aircraft is made to think that it is actually flying. Eventually we accumulated about 900 such "flight-hours", and meanwhile we did itinerary calculations using each day's winds to get statistics on likely flight times. It transpired that, on a good day, we might use only 3 kg of fuel for the crossing (out of 5 kg in total), and in any case the frequency of better-than-4 kg days was such that we could turn up our noses at anything worse.

The route and altitudes had to be selected to account for winds, icing, weather for takeoff and landing, and moreover for predictability: since the flight plan would be cast in onboard memory once the aircraft set out, it was important that we be able to rely on the forecast. Our planning drills culminated in a dry run during the first week of August, in which we coordinated launch, landing, and flight-planning groups through a complete flight plan and mission simulation. We still wound up improvising in the field, but the preparation showed through: *Laima's* arrival time was within three minutes of estimate, and the fuel burn within 5 percent.

Peer Frank photo

Bill Vaglienti talks with a BBC crew at the South Uist ground station. The red display behind him summarised the sad story: *Trumper*, expected early on the afternoon of 18 August, had not made contact and was by this time long overdue. Bill, a development engineer and the pilot for landing in Scotland, shared a tense and fruitless vigil with a crowd of visitors and his two crewmates from the University of Washington. The media were anxious to herald the story of *Trumper's* successful flight, but had to go home disappointed. Only a few locals were on hand for *Laima's* arrival three days later.

The media

Sooner or later our preference for quiet preparation had to conflict with the idea that this was, at root, a *media event*: publicity was the object of the exercise. By early July, with only a month to go, we decided that an announcement was in order to give reporters time to prepare. But we certainly weren't prepared ourselves for what happened next.

Eric Sorensen of the *Seattle Times* phoned instantly for a story. This wasn't what we had in mind: still chary of raising expectations, our thought was just to pass word that there *might* be a story in a month's time. Eric had already done a full-page piece during our Vancouver Island program in April, and I tried to explain that for now there really wasn't anything new to report. But I soon realised that we had been awfully naive about the news business: a bird in hand is worth two in the bush, and the name of the game is to print a story *NOW*. So the *Seattle Times* went to press with a big spread on July 11, including, for spice, some play about us being in a David-and-Goliath competition with Teledyne's enormous, and enormously expensive, *Global Hawk*. I had told Eric in passing about an Air Force idea of flying *Global Hawk* to the Paris Airshow in 1999; now, it seemed, the race was on to make the first unmanned Atlantic crossing.

With the floodgates parted by the *Times'* initial report, there was nothing to do but go with the flow. Calls, messages, and stories appeared steadily during July and on through and after the expedition, with welcome interest coming from lay and technical media worldwide. Accuracy was sometimes a bit weak, but enthusiasm was total, and we were indeed grateful for the stories that they produced.

The theme of "crossing the Atlantic on two gallons of gasoline" seemed to be especially popular. I was a bit surprised by this, as I explained to one reporter who rang a couple of days after a visit to our shop. She had most of her story, she said, but there was something she needed to clarify:

> "How can it cross the Atlantic on such a small amount of fuel?"
> "It's a small aeroplane."
> "Is it that simple?"
> "I don't know what else to tell you..."

The fuel burn actually turned out to be about 4 kg, or 1.5 US gallons. Really this was no impressive feat of efficiency. In terms of the relevant engineering measure (the "range equation") *Laima's* efficiency is less than half that of an airliner. We've left a lot of room for improvement.

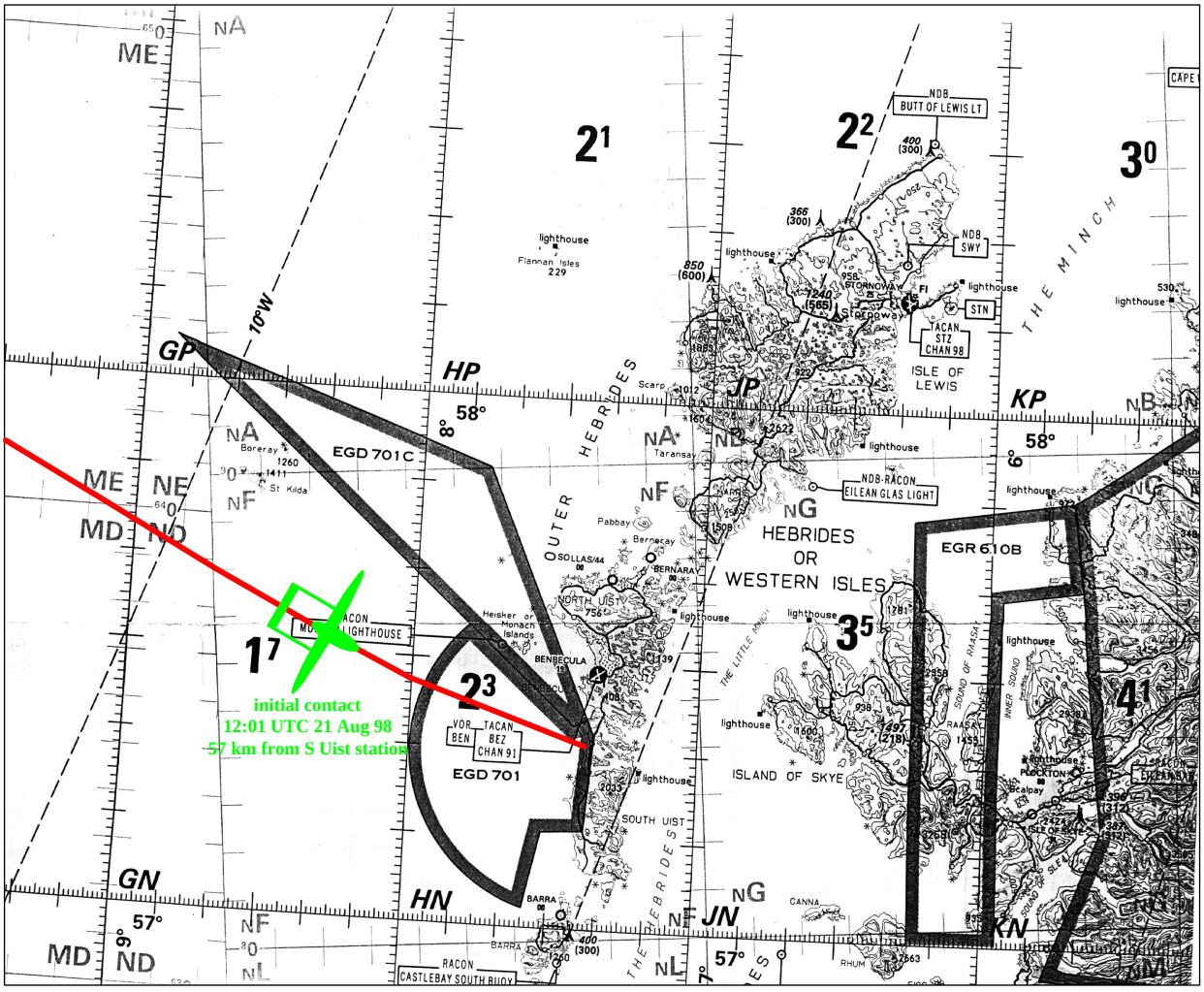
Putting out just one horsepower even when wide-open for climb, *Laima's* single-cylinder engine used three dollars' worth of gasoline to make the Atlantic crossing. The engine, highly modified from a model aircraft core, was quite efficient for its size, but still left a lot of room for improvement. Purpose-built engines in *Laima's* eventual successors will allow much longer range, and much better reliability.

A second, and rather more important, component of media interest involved the meteorological aspect of the program. Most reporters were careful to ask how weather forecasting was currently done; why lack of data over the oceans was a problem; and what the limitations were with existing observation techniques. This of course was as much a part of the message as anything about the aircraft itself.

The Atlantic Aerosondes

Our reckoning that we had more to gain than to lose in an Atlantic attempt was, perhaps, somewhat coloured by the fact that much of the risk involved someone else's money. The cost of the aircraft - about $25,000 apiece - was generously underwritten by the Aerosonde's long-

standing sponsors at the Office of Naval Research, through a grant to the University of Washington. Given the reliability seen in the spring field exercises, I had put the chance of success with any one aircraft at only about 50%. We would be wasting our time if we didn't take enough aircraft to make better odds than that. We decided on three, which, by the same shaky calculation, would reduce the chance of coming back empty-handed to only 1 in 10. The plan was to launch two on the first promising day, and the third if neither of those made it across.



The original transatlantic plan was to land on the west coast of Ireland, but the Irish authorities decided in late July not to admit Aerosondes to their airspace. We scrambled to arrange landing in Scotland instead, an alternative that was made possible only through the superb support and extraordinary speed of officials in the United Kingdom. *Laima* came in from the northwest at low altitude, and sent its first brief, teasing call to the South Uist ground station from a range of 57 km. Five minutes of breathless silence followed until firm contact was finally established, 26 hr into the flight and 44 km from landing.

Three new aircraft were selected from a batch assembled by our colleagues at Environmental Systems & Services in Melbourne. They arrived at our shop for finishing work in mid-July. Time was short, and became shorter still when we checked their fuel consumption data. Among

the unfortunate features of the current Aerosonde engine is a finicky carburettor, which, despite painstakingly adjustment during assembly, still shows lot of variation in fuel flow from one engine to the next. Two of the new aircraft proved to sit on the high end of the distribution, to the point that they would need hundreds of grams more fuel to complete the Atlantic flight. That was unacceptable, so our Australian friends had to scramble through data on their stock of engines to choose satisfactory replacements. New engines arrived in the last week of July, and we rushed to get the aircraft ground- and flight-tested in time for departure early in August.

Bernie Elsner, an airline-captain friend, put his airfield in the White Salmon valley at our disposal, and for a couple of weeks we rose early to fly in the morning calm. On many a summer day the Columbia Gorge is already gusty by 8 am, and we did not want to take *any* chances - at least not until we reached Bell Island. One day we tarried until after the wind started to blow, and had a hair-raising moment as *Millionaire*, Insitu's long-serving test Aerosonde, rolled to knife-edge on exiting the launch cradle. (Our first-generation cradle is a bit sensitive to crosswinds!) We had damaged several aircraft in such incidents before, but Kip Jackson, who was flying the takeoff manually, had learned to recover with rudder. He got out of it, and we were much relieved when all of the Aerosondes had passed their hour's flight check and were safely boxed for Newfoundland.

The Flying Scotsman

While we were doing all this - struggling out of bed to fly at dawn; frenetically composing our equipment; practicing the flight-plan drill; responding to media; arranging for travel - the Irish Aviation Authority faxed its decision. I was out flying at the time, and the report phoned from the office didn't sound all that serious. I took it to mean only that we would have to fly below controlled airspace, as by then we had anyway learned from Prestwick Centre. But when I read the fax itself, that afternoon, I realised that we had a serious problem: total exclusion from Irish airspace. The IAA couldn't accept the lack of enroute position reporting, nor the idea that one of our aircraft might come into the coast unannounced. We were facing our first ban in three years of flying.

This quite took the wind out of my sails for a bit, but that evening, back at Andy von Flotow's orchard, we planned a recovery. Our first priority was to try to get the IAA to change its decision, and toward that end we modified our proposal to allay some concerns. The key new idea was to send the aircraft not to the final destination, but rather to a holding circuit a few miles offshore. The command to come onshore would then have to be sent from the ground station, and so unannounced arrival (in the event of radio failure) could reliably be excluded. That proposal went back on 30 July, and meanwhile I asked the Irish meteorological service to put in a word on our behalf - as did Steve Lord and Cliff Mass. Met Éireann, which had been following our plans, responded with speed and enthusiasm. But its appeal was to no avail; over the next few days that IAA showed little interest in reconsidering.

However we meanwhile had started on the backup option: Scotland. Certainly the extra 200 km to the Western Isles was manageable, but more uncertain was whether, from a cold start, we could possibly get a plan together for an attempt in the 1998 season. My first inquiries were made tentatively and with much trepidation. However they led quickly to an exhilarating few

days of dealing with quite the most able and helpful group of officials that one might ever hope to meet (as indeed I still do; it was not necessary even to visit). Within two weeks everything was arranged: the landing site in the Hebrides; facilities on the ground; arrival procedures; authorisation from the Civil Aviation Authority; Notices to Airmen; clearance for our telemetry frequency; terminal weather forecasting from Royal Air Force Strike Command. It was a magnificent tour de force.

I had started on 30 July by calling Mike Ankers at Prestwick air-traffic control. Mike was, I think, a bit disappointed about having had to block us from his airspace, and he was only too happy to help in other ways. He immediately suggested the possibility of Benbecula in the Hebrides, a desolate and lightly-used place with special-use airspace conveniently covering the whole area. Taking it upon himself to make the necessary introductions, Mike rang back after a few minutes to say that Lt Cdr Ian Davies RN of the Airspace Policy Directorate was "ready to open negotiations." Ian in turn came straight to the point with a series of very sharp questions about technical details and safety provisions. (One of these, we were impressed to see, concerned the possibility of a "stop barrier" beyond which we would not proceed until establishing communications - *i.e.* exactly the new idea that we had just proposed to the Irish authorities.) Those questions having been satisfactorily answered, the proposal was put through the CAA. Meanwhile we worked on the landing site. Ian put us in touch with Major Scottie Garner of the Defence Evaluation and Research Agency, which ran the military range near Benbecula, on South Uist island. Scottie also moved quickly, and we soon satisfied each other that the landing site would be eminently workable. The DERA staff proved to be excellent hosts, offering hospitality and every support not only to our crew but also to the media and visitors who invaded for the event.

Thus the plan was complete in the first week of August. It called for a holding circuit 10 miles offshore, with the ground station on South Uist responsible for bringing the aircraft in from there. It also required us to enter UK domestic airspace at 58°N/10°W - a bit north of the direct route from Newfoundland - and to fly the 100 miles or so from there to South Uist at only 400 ft altitude. We were not entirely comfortable with 400 ft, since it called for very careful altimetry - and so an equally good weather forecast - to stay above the water (not to mention any ship masts). However it made all the difference. The UK, like many another country, has various exemptions in place for model aircraft so long as they keep below a certain ceiling - *i.e.* 400 ft. These rules were hardly written with ocean crossings in mind, but they could nevertheless be made to fit - and so obviate the need for a lengthy technical review. In flight as in song, the low road was the fast route to Scotland.

The adventure begins

The official letter of approval from the CAA arrived on Monday 10 August. Our gear left for Newfoundland that afternoon, and the landing party - Bill Vaglienti from Insitu, and Steve Huffman and Greg Lipski from UW - flew off to Scotland the next day. There was little time to lose. Commitments at the end of the following week awaited my two companions in the launch crew: Kip Jackson, the pilot, and Ross Hoag, the engineer whose meticulous husbandry of field hardware was essential to all of our flight operations. Margins had become disconcertingly thin; we would have only a few days to catch acceptable weather.

We left for St John's on the Thursday night. Next morning, on the flight up from Halifax, I gazed out across the Atlantic, placid but immense and forbidding all the same. I had by then caused tens of thousands of dollars to be spent, and compounded that investment with the extraordinary efforts of people scattered over three continents, and now it was all on the line for the preposterous illusion that, only a few days hence, one of our puny toys would survive out there beyond the edge of the world. It was surreal.

There was little time to feel overwhelmed: we had made our plan and we hit the ground running. Still, my grip on reality was hardly improved by being given the job of getting the gasoline. Here I was, first browsing the caverns of Wal-Mart for two jerry cans to supply A TRANSATLANTIC FLEET, and then presenting myself at the airport Esso in hopes of actually buying some aviation fuel. The staff eyed me suspiciously: company policy, it emerged, told them to beware of geeks bearing jugs. I tried to imagine a persuasive way to establish my *bona fides*, but even lying a little by saying that the fuel was for only *one* Atlantic crossing seemed unlikely to be convincing. Stymied, I retreated to Shell, where fortunately they had no qualms about how clients carried off their purchases. The bill came to C$28.43. And so, with my few hard-won litres in hand, I embarked on the *MV Flanders* for Bell Island.

Kip and Ross had deposited our gear at the airport, and found the facilities, and the welcome, as accommodating as we could possibly imagine. The three of us were adopted for the duration by Gord and Marilyn Shea, both Bell-Island born, and now Bell-Island returned in retreat from the bustle of southern Ontario. They became our superb hosts in sharing the ups and downs; the comings and goings; the continual calls and harrowing waits; and the ultimate triumph of the week to come.

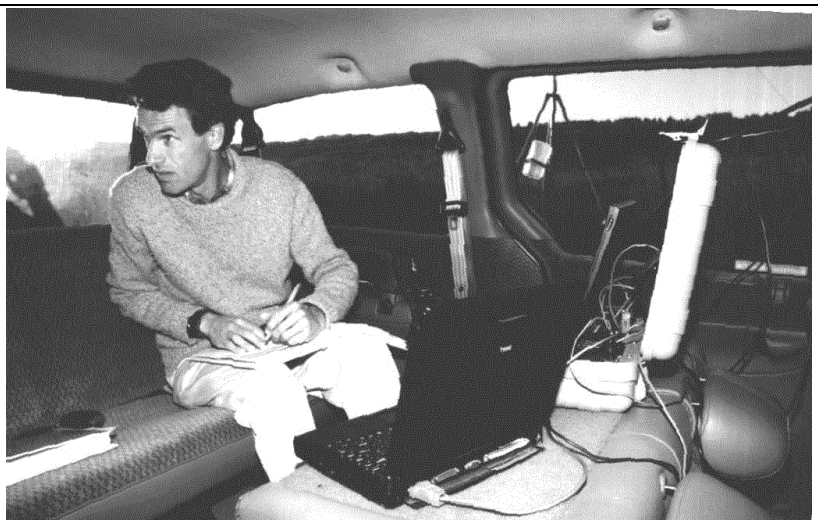
I had checked the long-range weather forecasts with Cliff Mass while passing through UW two days before, and, while initially discouraging, the expectations turned out to have improved. By Saturday morning, the Sunday and Monday were shaping up to be excellent launch opportunities. Bill's landing party had by then done the preparatory work at the Scottish end, and we worked with a will to be ready at ours - preparing two aircraft, checking equipment; surveying the runway; doing simulations - but then we ran into a problem. The Web site with the Atlantic wind forecasts, which until that day had been updating every 12 hours for weeks, suddenly wasn't. Even though we knew that the weather was good, we could not do flight planning and fuel estimates without those vital wind numbers.

It became essential to find Steve Lord in Washington on a sultry August weekend. Directory Assistance put me through to several Steve Lords in the Washington area, but none seemed to know or care very much about weather over the North Atlantic. I switched to a Web search, and eventually, through a balky long-distance connection that kept hanging *MS Explorer*, teased out a home-phone number. But that only led to Steve's answering machine: not necessarily better than his e-mail boxes, by then cluttered with frantic appeals - some of which, ominously, had bounced back undelivered. Increasingly desperate, I tried again that evening and found Steve just as he arrived home from vacation! It wasn't much of a welcome: after midnight he called back from his office, where for several hours he had been battling a crashed disc and a broken server. By

then the chance for a morning launch was long gone, but the next day, with much phoning and improvised internetting of data between Washington, Seattle, and Bell Island, we got ourselves organised for an attempt on Monday.

Between these scrambles we did a short shakedown flight late Sunday afternoon, using *Millionaire*. The flight turned up some data-communication anomalies as we circled over the airfield under manual control, with the autopilot having to take over several times when signals from the ground station were blocked. Similar, albeit unreproduceable, anomalies had led us to scrub some test flights back home, and we had attributed them to use of an unfamiliar frequency band. (We normally communicated at about 420 MHz, but had moved down to 406 MHz for the Atlantic program in order to satisfy European spectrum rules.) The fades were unnerving, but it looked as if we would have to live with them.

Our first pair of Atlantic aircraft, *Trumper* and *Piper*, were left fueled and ready at the airport. Flight-planning work continued into the night. Meanwhile the boys in Scotland were all set - Bill having by then mollified Her Majesty's Customs and Excise, which had got wind of the itinerant robotic tourist and insisted on stamping her passport! The crew was anxious, suffering under the pressure of an assembling multitude of visitors, and further sapped by Hebrides isolation and relentlessly bad weather. Yet it was not so bad that they couldn't manage some sort of landing - *if* an Aerosonde made it that far.



Keith Gosse photo

The author glances out from the ground-station van while completing *Trumper's* logbook, a few minutes before the first Atlantic launch on 17 August. Two laptop PCs display telemetry, relayed through an antenna on the tripod outside.

Launch

On launch morning we were up around four to check the final flight plan, e-mailed overnight from Seattle. Cliff Mass and Scarlett Bendana, an undergraduate in Aeronautics and Astronautics, had been up late watching the forecast. The weather was holding: launch was definitely on. I transcribed the route for loading into *Trumper*, with a final simulation just to be

sure. Dawn came up as we arrived at the airfield. It was windy, as forecast, and clear with a lovely view down Conception Bay into the maw of the Atlantic.

The familiar drill kept us moving through pre-flight, but the stress was inescapable, and our edginess mounted as, for the first time in our experience, a crowd gathered to behold the proceedings. The Bell Islanders had quickly taken a proprietary interest in the whole adventure, and launch was an event not to be missed. As the time for engine-start approached, Kip and Ross signed *Trumper's* fuselage. My talisman was in the avionics bay, a set of pilot's wings given me years before by John Blackmore - the *Spitfire* pilot and kindly, firm, and thoroughly decent model of a headmaster who had been a friend and flying companion since grade school in Vancouver. He had died just months before; *Trumper* was named after one of his beagles, which is about as much of a memorial as he would likely have countenanced.

I addressed the audience briefly, with thanks and a word of advice that *Trumper*, being a prototype aircraft, should be trusted only as far as it takes to run for cover. Everyone dutifully retreated behind the line of cars parked off the airport road. We drove the launch car back and forth on the runway to check communications, and, while there were hints of communications fades, they seemed small enough to be manageable.

Trumper leaves the launch cradle, 7:14 local time on 17 August. Minutes later, after some checks over the Bell Island airfield, she was sent down Conception Bay and out into the Atlantic. Everything was normal when she disappeared behind Cape St Francis, and she was due in Scotland about 24 hours later. But *Trumper* never arrived.

We launched on schedule and took a few minutes to verify performance over the field. Then the time had come. It required only that I enter a new waypoint on my laptop, and *Trumper* would start along the programmed track to Scotland. In simulation after simulation it had been just three casual keystrokes. But now my fingers hesitated. Ross and I considered the enormity of the moment. We decided to go.

Trumper was out of sight in a trice. We tracked her on the laptop, switching to a longer-range antenna as she move down the bay, and finally lost signal behind Cape St Francis with the aircraft 40-odd km from takeoff. In other circumstances, loss-of-contact would have brought apprehension. This disappearance, however, took a weight off our shoulders. We had all been worried about *screwing up*, about some unspeakable catastrophe scuttling the enterprise before it had even begun. But now we were off according to plan; *Trumper's* wind reports were as forecast; and all of our telemetry indicated that she was well on her way. Only time would tell.

We had a break in the sun. Three hours were planned between *Trumper* and *Piper*, to allow for some uncertainty in flight durations along slightly different routes - and for the extended ceremony that would doubtless follow landing in Scotland! Interviews and photography filled the interlude. Then back to work, and, as we went through the pre-launch checks on *Piper*, the communications problems had become worryingly worse. Yet they were not easily reproduceable, and, after protracted tests proved inconclusive, we had to make a decision. Clearly we were facing a significant risk of intermittent communications loss, but the autopilot would take charge if manual control was blocked during takeoff. Having come this far, going ahead was our best option.

Ross Hoag and Kip Jackson rest *Piper* on the ground beside the Bell Island runway, just before turning power on to run the preflight checklist. Both were veterans of fours years of development and field trials, Ross as the engineer overseeing all flight hardware, and Kip as technician and pilot. But the North Atlantic was a challenge like no other.

Launch was fine, and we had no problem until about 30 seconds into the climb. Then there was a communications fade, and the autopilot came on automatically - but, instead of flying ahead smoothly, it put the aircraft into a rapid left roll. The nose dropped straight down, and *Piper* disappeared behind the cliffs in a rolling dive - followed after a couple of seconds by the sickening thump of impact in the water.

Even more sickening was the diagnosis. After reviewing telemetry and checking the flight software, I realised that I had made a mistake in the code. It turned out that the autopilot was not being initialised properly when it came on automatically (as opposed to the usual enabling by ground command). Often the initialisation would nevertheless be okay, as indeed it had been on those rare occasions over the 4 previous years when we had had similar blockages of manual control. But I could recall quite a number of instances on the ground - including those during *Piper's* pre-flight checks - when interrupted communication had caused the ailerons to jump. Had I given this a bit of elementary thought we would have saved $25,000 - and perhaps more had *Piper* made it to Scotland!

Ron Bennett photo

Ross Hoag holds *Piper's* mangled electronic brain, retrieved from the water below the airport in an afternoon salvage expedition mounted by ever-helpful Bell Islanders. A communications outage shortly after takeoff had provoked an obscure error in the Aerosonde's autopilot software, and *Piper* dropped in a rolling dive beneath the Bell Island cliffs. A change in pre-flight procedure avoided the problem on subsequently launches.

But now *Trumper* carried all of our hopes. In St John's that afternoon I stopped where Alcock & Brown had taken off a lifetime before. The site was long since engulfed by the spreading city, and, standing on a busy corner, I had to strain to imagine the clamoring takeoff and leaden climb of that overloaded Vickers bomber. It carried not merely their hopes but also their lives, and very nearly took them. John Alcock was forced, with mixed results, to improvise instrument flying in those days before instruments, while Arthur Brown had to chance a night wing-walk to chip ice out of their engines' strangling intakes. We lesser pioneers crossed the Atlantic while snug in our nice warm beds.

Snug indeed, and, despite the worry, tired enough to sleep. *Trumper* was due about seven Newfoundland time, and I turned in with the fatalistic hope of someone shaking me awake, red-hot telephone in hand. When I eventually woke of my own accord, sometime after seven, just the daylight in the room told me that hope was already faint. We stuck it out through the morning,

the phone stubbornly silent except for the odd caller wanting the latest report - and to whom we could only say that no news was bad news. Eventually Bill rang from Scotland wondering how long to stay on watch. It had already been a very tough day for his crew, waiting forlornly together with an audience of expectant media, anxious officials, and sundry restless friends. When *Trumper* was a few hours overdue it was time to pull the plug.

Now we steeled ourselves to face it all again - or worse, not to have the chance for lack of fair weather. *Laima* was on deck, named by Juris Vagners, drawing on his Baltic heritage, after the ancient Latvian deity of good fortune. At that point we would take our luck wherever it could be found.

But we weren't allowed to let *Trumper* go so cleanly. That afternoon we were back on the runway, verifying the diagnosis, and the cure, for *Piper's* crash, when Bill rang urgently from Benbecula. They had been called about an aircraft fitting *Trumper's* description, flying at low altitude, 100 km to the north over Stornoway! It was hard to imagine: it would imply failure of both navigation and range safety, compounded by flight endurance at or beyond expectation, and moreover by some byzantine evasion of the mountain range between Stornoway and the ocean. Nevertheless we had to investigate quickly, and I left Bill to do what he could while I rechecked the flight plan in *Trumper's* telemetry. It was correct: there was no question of having sent her to the wrong place. Presently Bill called back, having boiled the commotion down to two reports, and only one of those described something at all like an Aerosonde. A mistaken witness, however, seemed far more likely than *Trumper* actually materialising in the area that was claimed. We decided that a search would probably be a wild goose chase - but still left word with the local police, just in case. Then on Wednesday we received yet another in-flight report, now more than two days after launch. *Trumper,* it seemed, had transmuted into a robotic *Flying Dutchman.*

A second chance

Weather precluded launch on Wednesday, with the Hebrides even more dismal than usual, rain in Newfoundland as well, and poor winds enroute. But Thursday looked more promising, so we geared-up flight planning and aircraft preparation to have another try.

We had to run *Laima's* engine for a while to check oil consumption. At home it had seemed high at idle, but a retest at cruise power turned out to be satisfactory. *Laima* was cleared to go. Then our eyes wandered to *Millionaire.* She was one of the original ten Aerosondes, built by Insitu in 1995 for our first Australian trial (and named, following a dinner at *Gilligan's* in Darwin, after the cast of television characters). She had last flown offshore at the Oregon coast in 1996, and in test work since then had gone through countless engines, wing sets, and sundry modifications and upgrades. We hadn't planned for her to take an Atlantic adventure, but, having come this far, we had to shoot our bolt. We fitted her with the last of our batch of lean-running engines; tested her on the ground; and had a pair of aircraft ready for the morning.

By this time Steve Lord's wind server was back in action, but *Windows* data-transfer was still crashing continually as it grappled with the long-distance lines from Benbecula and Bell Island.

Truly impressive phone bills ran up as we tried to coordinate the far-flung flight-planning operation. But by late afternoon in Seattle, Cliff Mass and Scarlett Bendana were offering a route south of the great circle through winds around a mid-Atlantic high. The estimate was about 26 hr enroute with 1.2 kg fuel remaining - not as good as Monday's numbers, but certainly good enough, and the weather for arrival in Scotland was expected to be quite tolerable. There would be a lot of rain and convection over the ocean, but, based on our experience in tropical thunderstorms and British Columbia downpours, I had told Cliff that rough weather would not be a problem.

And so on Thursday we repeated the pre-dawn launch preparations. First light at the airport showed good weather, with high clouds and moderate winds, and a crowd of ever-encouraging islanders assembling to lend moral support. Preflight turned up a few communications fades, and before starting to roll I made quite sure of a good initialisation should the autopilot come on automatically. We launched just before 7:30, and 30 seconds later I called for Kip to enable the autopilot. *Laima* was then out of the danger zone. Overhead checks were fine, and then it was again time for the fateful few keystrokes that led off to Scotland. By 7:40 *Laima* was out of sight. We tracked her down the Bay at 350 m altitude; the air was smooth; the wind west at the forecast 15 kt. Half an hour later we lost contact off Cape St Francis, with *Laima* running as well as we could wish.

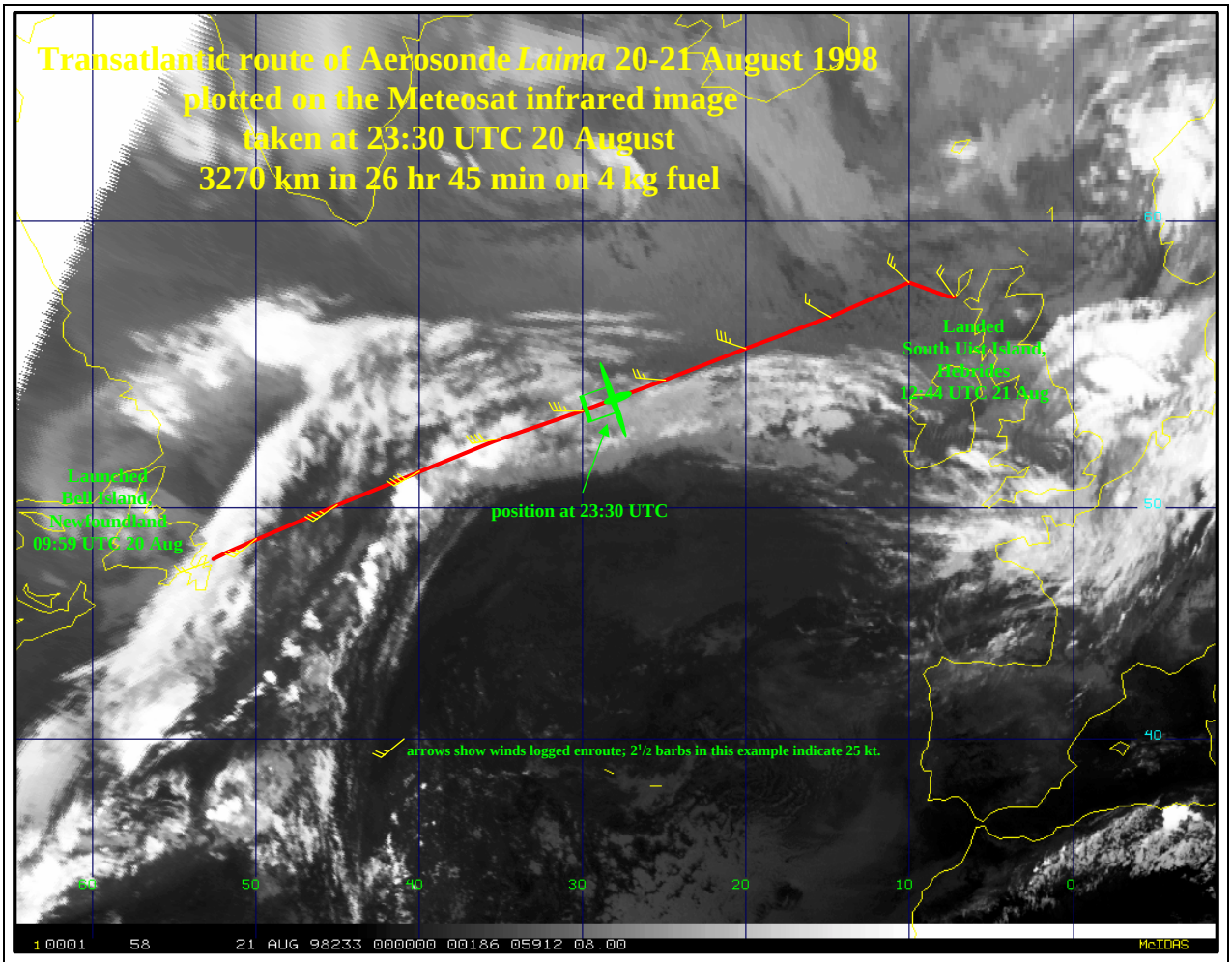
Three hours later *Millionaire* went down the same track. Her performance was much the same, except that the cylinder head was running on the warm side. After launch we had had to nurse her up to avoid overheating, but, with cruise temperatures settling back within acceptable limits, we had decided to go ahead. *Millionaire's* signal vanished at 11:20, just where *Laima* had gone before. Now both dice were in the air.

Kip was instantly in a car and heading for St John's - he had stayed an extra day for the Thursday launch window, and now he was overdue back home. Only the packing-up was left for Ross and me. We had our equipment off the field by noon - and then wondered how we managed to fill all the boxes despite being three Aerosondes short! After a few hours the gear was packed, and the bulletins posted, and more interviews done for a press still steadfast and eager. Then we slipped into tourism, with a peer through one of the labrynthine iron mines sprawling out beneath the Bay. Hard evidence indeed of a cold, dark, tough life for little reward, but a life which had made Bell Island a thriving, chimney-puffing place in the days when Lindbergh and Earhart had passed overhead. Now the pace was much slower and the island traded on charm.

Our ship comes in

First thing Friday morning I checked the itinerary updates, which Greg Tyrrell of the Melbourne group had calculated using the overnight wind posting. *Laima's* arrival at the holding circuit was still expected about 10am Newfoundland time, so contact with the ground station was likely between 9:30 and 9:45. *Bonhomie* had kept tension at bay the night before, but now we were all tightening like drums - Ross, me, Gord and Marilyn Shea, the crew at Benbecula, and a few keeping late vigil in Australia. I took a walk along the cliffs, relieved by the warm, azure day, and telling myself that, after all, perhaps just making the attempt had accomplished most of our

objectives. It might not happen today, but already we had broadcast the message that robotic aircraft were a'comin' in.



Laima's transatlantic flight plan took her south of the great circle route to sail in favourable winds along an occluded frontal zone. Here the long band of frontal cloud is shown midway through the flight. Her planned altitude was 1680 m (5500 ft) to 58°N/10°W, the specified entry point to UK domestic airspace; she then dropped low over the water in order to qualify, according to a sympathetic interpretation of aviation regulations, as a model aircraft. Some model indeed.

Ross and I had our freight to ship home, and we queued for the 9:50 ferry. I strolled, or perhaps paced, by the quay, integrating as I imagined through some Gaussian curve of probable contact times. Seen in this way, half of our chance of success would already have slipped away before the expected time of arrival - a hard business to endure, particularly when our chances with *Trumper* and *Piper* had already been lost entirely.

My pocket phone rang at 9:40. The Gaussian slipping stopped; very nearly my heart as well. The voice at the far end was channeled into classic NASA-controller monotone:

"This is Bill. We are in contact with *Laima*."

Mine was not:

"*FAN-tastic!*"

Bill checked a point about setting *Laima's* altimeter and then hurriedly signed off. I ran back toward Ross in the ferry line, thumb high in the air. "*We're in!*" Elation, relief, and pure happiness flooded through us, and it was hard to collect our thoughts. The post-contact protocol hadn't been part of the rehearsals. "*Who do we call first?*" Ross called his wife. (It was 5:15 in Hood River). I decided on Marilyn Shea, who at that moment was probably more wound-up than anyone; she burst into tears. Then down the list: Kip; Andy von Flotow; Juris Vagners, all in bed on the west coast; Greg Tyrrell waiting up in Melbourne. But it turned out that the Australians already knew.

We found out much later that the Melbourne group had cracked under the strain and called Benbecula. On their first try the phone had rung and then been hung up; they tried again and were dismissed with a terse "*It's Laima! Gotta go!" Laima* had just then started to toy with the Benbecula crew. At 13:01 (local time) she did a periodic wind-measuring maneuver - an S-turn around track - and so briefly flashed her antenna favourably toward the ground station 57 km away. It was just enough to squeeze through a short burst of telemetry. The ground-station PC, which had been torturing the crew for hours with impassive silence, suddenly piped up with a beep and a new colour to show active communications. Then nothing. *"Was that Laima?"* Bill, who well knew the communications software, insisted that it really couldn't be anything else. But there were five long minutes of electrified tension before the oracle spoke again, finally in firm contact at a range of 48 km. Then the tension released and the control room exploded.

Greg Lipski went through the arrival checklist, and uplinked new waypoints to bring *Laima* onshore. She slipped in past the surveillance radars on Benbecula and St Kilda islands (which, despite knowing where to look and trying hard, didn't see a thing). At 13:40 she crossed the beach and entered a circuit of the landing field. Control was then switched to a second ground station: the long-range operation was done from a blockhouse inland, while the landing had to be flown from a Land Rover parked down on the field. Little time was wasted. Bill turned up from the laptop and there was *Laima*, brilliant white under the scattered cumulus charging in from the Atlantic. He quickly selected manual control and wheeled her steeply into the chill 20 kt breeze. *"ENGINE OFF!"* Two keystrokes from Steve Huffman stopped the propellor for landing. Touchdown was a gentle plop into the tall grass - whereupon, as Eric Sorensen of the *Seattle Times* put it in his account, "researchers and a handful of onlookers erupted in cheers and hugs."

"We have something you lost" said Bill's monotone, back on the phone as the *Flanders* pulled into dock at Portugal Cove. Ross and I drove on to St John's in a state of total relaxation, and unhurriedly ran our errands in town. Even *Millionaire's* arrival time came and, sadly, went, with only a faint echo of the morning's worry. It was also sharper: *Laima's* trailblazing had narrowed *Millionaire's* Gaussian, and we had to count her out shortly after lunch. For our senior Aerosonde it was a poignant final curtain, but easily seen as an honourable and glorious finale. For us, that day, all sides were incorruptibly bright.

When Bill next called we were back on the *Flanders* for the return trip to Bell Island. Our first thought was for *Millionaire*, but it was clear by then that there was little hope, and none was on offer. We agreed to call it quits after another hour or so. Meanwhile there was more information

on *Laima*. Her nose boom, for measuring static pressure, had snagged in the tall grass and ripped out on landing, but that was incidental. More remarkable was a load of rainwater found sloshing in the avionics bay. We had been doubly careless: first, having run out of our preferred tape for sealing the wing/fuselage junction, we had used a poor substitute that the rain had undermined; and second, we had not made a drain hole! *Laima's* Latvian luck had been with her all the way.

But there were more than just Baltic deities to thank. The plethora of enthusiastic help and encouragement that the Atlantic program had enjoyed deserved a gratitude that I could hardly express. Back on Bell Island I sent off a few messages, swept up in the flurry of e-mails that were by then ricocheting round the globe. No form of words would even begin to seem adequate.

Laima sits in the South Uist grass with her landing crew: Bill Vaglienti, Greg Lipski, and Steve Huffman. In addition to her remaining kilogram of fuel, she carried a puddle of water collected during what must have been a lengthy transect through rain in the mid-ocean frontal band. Gracious and patient hosts of the UK Defence Evaluation and Research Agency had dispensed large rations of scotch to sustain the crew through a wearing week, but now the celebrations could begin in earnest.

That afternoon I stood in the warm sun on a cliff overlooking the brilliant turquoise of Conception Bay, stared into a television camera, and considered whether I was surprised. No, I told my interviewer, not surprised. We wouldn't have come without good reason to expect a successful result. But on the other hand, when considered in purely visceral terms - tiny aeroplane, big ocean - the whole idea had, admittedly, seemed pretty far-fetched. And this is really the compelling conundrum that draws one into such an enterprise: if one fails one is puzzled; but if one succeeds, one is *amazed. Amazement* - that sort of amazement - is surely one of the great pleasures that experimental science has to offer. And what pleasure became ours to share! So it was shared that night, not least in the pubs of Benbecula and the boisterous salon of the Sheas' Bell Island home.

The next day *Laima* was boxed up and squeezed aboard the Saturday flight to Glasgow. Bill really had had to clear her through customs for coming into the United Kingdom, but, with an exquisite bureaucratic symmetry, her papers were thus perfectly in order when the time came to go back out again! She wended her way slowly home to Seattle, and into retirement at the Museum of Flight after a career of only two flights.

Our gamble had paid off in full measure. An attentive media soon fulfilled all our hopes by reporting *Laima's* success far and wide. Where previously the idea of long-range operations by miniature robotic aircraft had been a bit of conceptual esoterica, now it had become a well-known fact on the ground. And in the collegial circles of meteorology and aviation, the possibilities for routine service suddenly seemed a lot more real, and a lot closer. Much engineering remains to be done, both to achieve satisfactory reliability and to make these small aircraft much more efficient and long-ranged. But the path ahead is clear.

An interviewer asked why all of this hadn't been done before. It was a good question. The first robotic aircraft had predated even Alcock & Brown, and the engineers of forty years ago doubtless could have managed an Atlantic crossing between their busy expeditions to Mars and the Moon. But it would have had no point. Nobody was prepared to pay the huge bill that a transatlantic aircraft would then have carried, nor, moreover, to make use of the information that it might have supplied. *Laima's* moment came at the convergence of need and opportunity: need created by fast forecasting computers and their voracious appetite for a steady diet of environmental data, and opportunity by modern technology in its manifest forms: GPS, of course, and other small and cheap novelties carried onboard, but also the laptops and cell phones and Web connections upon which we relied on the ground (and indeed, at whose mercy we were sometimes left to fume and flail). One might have expected the rush of technology, and particularly of remote-sensing satellites, to leave far behind the quixotic notion of a little toy aeroplane slowly poking its nose hither and yon into faraway nooks of atmosphere. Instead it conjures it up insistently, and thrusts it onto the widest stage on the globe.