

FLARM Compatibility Considerations

Summary

We argue that FLARM's low cost collision warning technology and its licensing framework are in the best interests of the sport and its participants, are the only cost-effective way to manage and refine such a technology and caused it to be its main reason for success. This document describes some of the thoughts behind the current compatibility framework and points to issues and challenges that arise if other solutions were sought.

The uncontrollable proliferation of parasitic devices with untested and largely untestable compatibility and performance is undeniably not in the interest of flight safety and thus contrary to our mission. Unless a superior solution is available, we will exercise all necessary legal and technical actions to ensure the FLARM technology remains safe, expandable and affordable.

Current situation

FLARM is an affordable collision-warning system for General and Sport Aviation based on private initiative. It is the only prevalent alternative to ACAS, the system mandatory for bigger commercially operated aircraft. FLARM is designed to minimize nuisance alarms even in high traffic densities and with unsteady, dynamic flight paths.

As of autumn 2007, FLARM-compatible devices are available from six independent companies¹ offering a total of 10 different products. Further products have been announced, and other manufacturers have licensed the technology and are expected to announce products in due time. This fast take-up by incumbent avionics manufacturers for a previously not existing market is largely due to the simple and efficient licensing framework which we have made available from the beginning and remains unchanged. Flarm technology's current share of the market is below 50% and declining, which shows how well the market already works.

Over the last four years, well over 10'000 FLARM-compatible devices have been installed in aircraft worldwide. The devices have been credited on many occasions with avoiding dangerous situations and increasing situation awareness.

In 2007, FAI (Worlds Air Sports Federation) awarded FLARM the "Prince Alvaro de Orleans-Borbon" prize for "Technical Advances in the Field of Sporting Aviation". In 2006, FLARM won the OSTIV (International Scientific and Technical Soaring Organisation) prize "for their great contribution to sailplane safety".

Compatibility requirements

The communication protocol containing all the information received through FLARM compatible units is available publicly from www.flarm.com/support/manual ("Data Port Specification"). This protocol is based on the industry-standard NMEA-0183. It is being used by numerous periphery manufacturers as well as most PDA flight management software suppliers. The additional binary communication protocol which handles e.g. the download of flight records or upload of new data and firmware is available on request.

In the very early design and test phase of FLARM we assumed that the radio communication protocol - developed, written and copyrighted by Flarm - could eventually become an open standard to allow other interested parties to build compatible devices. Consequently, starting in March 2004 we made a first draft

¹ LX Navigation (Slovenia), RF-Developments (Australia), Triadis (Switzerland), Ediatec (Switzerland), Artronic (Switzerland), Flarm Technology (Switzerland)

protocol for the RF communication available to specific interested parties on request, also within the IGC Annual Meeting. In the subsequent months and years we received no replies or contributions to that document whatsoever.

By the time the first devices shipped in mid 2004 we had learnt that the complexity of the problem extends far beyond defining and implementing of just the RF protocol. From then on we communicated to all interested parties that we only support other manufacturers through our “compatibility by design” framework, intrinsically related to the licensing system as this is the most efficient way to ensure full compatibility between all manufacturers.

FLARM licensees receive design information and incorporate the well proven design to minimize development cost and time to market. Manufacturers build upon our proven know-how and experience. We provide hardware design information for a core module which is adapted by the incumbent avionics manufacturers into their own design process. We deliver software code containing the core functionality and algorithms while the licensees design their own functionality around to serve different users’ needs. Design and software code together form the basis for the production of the devices. This integrated workflow ensures compatibility by design, significantly reducing the need for testing and debugging. The track record of this “compatible by design” framework is outstanding. No malfunction related to compatibility between FLARM licensed devices has ever been reported.

Necessary steps to achieve compatibility

If FLARM were to follow an “open system, compatibility by specification & certification” approach all of the following, purely technical, topics would have to be considered in detail to ensure compatibility and best system performance:

Sensor data processing

For aircraft operation in close vicinity of each other (e.g. helicopters, gliders) highly accurate relative position and speed vectors are essential to support the pilot with situation awareness. Thus processing of sensory inputs is crucial. In example, we conclude that the type, filter setup and even the firmware version of the GPS module used must be considered in detail. The internal filtering algorithms of GPS products vary greatly but are highly proprietary and are therefore not entirely published by the manufacturers. A comparison between different GPS products can only be done with extensive flight testing and would need to be redone with any future firmware changes of the GPS manufacturer. Internal post processing of the GPS data must also be considered.

To circumvent this problem, all FLARM compatible devices use the same GPS type and firmware, and as a consequence of the high volume of GPS units used for FLARM-compatible devices, we also have access to confidential in-depth information and support from the GPS manufacturer. Similar considerations apply to the barometric altitude sensor signal.

IGC is well aware of these issues, as this is one of the key reasons for still requiring barometric sensors in flight recorders. Furthermore IGC’s GFAC has extensive evidence about the variations between different GPS-modules. The problem for FLARM-compatible devices is further aggravated, as precise relative 3D positions and speeds are required for collision avoidance and GPS antennae may be blanketed while circling, leading to unpredictable variations in GPS output if dissimilar devices were used.

Flight path prediction

FLARM is based on a system of local and high-frequency flight path prediction, which is superior to other solutions because every unit calculates its own forecast based on all locally available data and its history. The transmitted data thus includes all the information required to allow the receiving unit to make an immediate threat assessment. Since we are only interested in the development of relative distances it is more important to have the same algorithms than to have the “best”. Therefore, a fully compatible system needs to run the exact same prediction algorithms. This is even more important when conflict resolution advisory is targeted

which is required for some future applications. This technique also has obvious advantages with aircraft whose path is predetermined or highly predictable.

Updates and backward compatibility

All FLARM compatible devices are subject to a mandatory periodic full update of the firmware allowing for major improvements and evolution of the technology to advance flight safety. This update can easily be performed by the user. Thereby, even early devices maintain the full compatibility without being limited by constraints of the past. This has been recognized as one of the core strengths of the FLARM system design and has helped it adapt to expanding requirements in the past.

Furthermore, if the FLARM technology is ever abused, we retain the possibility to modify and improve the protocol without concerns about backward compatibility. To allow this unlimited updateability, compatible devices must be similar in their hardware and -software implementation.

Confidentiality of transmitted data

FLARM transmits information that is required for collision warnings which, under given circumstances, the sender would prefer to keep confidential. If the RF-protocol were to be open to the public this detailed transmitted information could be used by anyone which could be undesirable e.g. at competitions, or in the context of incidents. The current FLARM implementation allows the user to choose if all information should be available on other units data-ports or if some (e.g. climb rate, device identification) should be omitted.

The implementation of these "Privacy" settings must be exactly the same on all available devices, as a deviating implementation will give that user an unfair advantage – see also the corresponding ruling by both FAI and IGC. To ensure fairness and maximum flight safety at competitions one could even argue that the competitors should be prohibited from tampering with their FLARM equipment as some may otherwise be tempted to transmit false or truncated signals.

The non-standard implementation of this would violate IGC competition rules² and could possibly lead to a ban of FLARM devices at international competitions, or in countries with excessive privacy protection rights.

Radio frequency transmission

Designing a low-power short-range RF-communication for highly-selective and reliable collision-avoidance poses a series of technical challenges, considering the massive local clustering of gliders in the same or near thermal or flying at high speed in dolphin-style just at cloud borders. Therefore the RF protocol has implemented a series of inventions allowing to greatly improving the overall and local system performance, such as the minimisation of message length, duration and frequency, the maximization of bandwidth usage and communication reliability and the inexistence of fixed limitations regarding the maximum number of nearby aircraft. On the other side, this requires that no other system tries to partially emulate the same protocol, otherwise the performance degrades for all users. The protocol also includes provisions for airspace users with "unusual" and highly dynamic flight patterns like parachutists, para-gliders, RC aircraft and UAV's. Based on extensive R&D and user-feedback, the next generation of the RF-protocol for added flight safety is currently finalised and is the basis for the mandatory firmware update announced for early 2008.

Human interface and ergonomics

The design of the human machine interface is left to our partners. They may use FLARM's built in threat assessment algorithms, or choose to implement their own. However a majority has chosen to use the system provided by FLARM which has the added advantage that pilots can use systems from different manufacturers without retraining and confusion.

The proliferation of advanced, fully graphic "Radar" type displays should be discussed and its benefits independently evaluated.

² President's Letter to Delegates and Committee Chairmen, 2005-6, available from <http://www.fai.org/gliding/p240705>

Miscellaneous, proprietary COTS hardware

For a truly open specification no part of the hardware can be supplied by a single, proprietary source, therefore also the hardware for transmitting the RF signal would need to be specified in a technology independent way, while also considering the IP rights of said supplier in alternative implementations. The same principle also applies to other system components.

Specifications

Based on the topics above, the scope of a full compatibility specification is broad and in many cases a bit-accurate implementation and extensive compatibility testing at each major revision would be required. Writing and maintaining such a specification would require many man-years of work and multiple iterations. This is the reason why e.g. ADS-B specifications cover hundreds of pages. Even the rather simple “Technical Specification for IGC-approved GNSS Flight Recorders“ currently runs at 70 pages and flight recorders do neither require radio communication nor cooperation between multiple devices in real-time. It is difficult to envision how the FLARM system could remain affordable if it required such an administrative overhead.

Testing

The tests to verify compatibility would need to consist of code reviews, software tests with near 100% code coverage, simulations and various in-flight tests for each of the above mentioned issues. We estimate the costs for each test cycle to be tens of thousands of Euro. These tests would have to be repeated for any major code or algorithm changes. In addition, the tests required would need extensive specification, proofing and documentation.

Certification

The compatibility, based on above explanation would need to be certified by an independent body, which would take over responsibility and possibly liability for the systems performance. Liability is a prime concern for these type of devices, unlike with flight recorders.

The administration of such a certification process would be orders of magnitude more complex than e.g. the IGC Flight recorder certification, as Flight recorders are stand-alone devices, have become a mature technology and do not include the inherent technological complexities of a RF cooperative, real-time system.

Intellectual property considerations

All of the above technical compatibility considerations can be discussed independently from licensing and intellectual property rights, but these must nevertheless be considered.

Various IP rights

The area of combining GPS and radio for traffic control and collision avoidance is covered by hundreds of patents, some of which clearly apply. OEM manufacturers licensing our core design can also sublicense intellectual property rights FLARM owns and has acquired, partially from 3rd parties.

With respect to negotiations with IP owners, we consider it much more efficient to maintain a single contact rather than each manufacturer having to delve into the details of worldwide patent laws, which quickly accumulates huge costs.

FLARM Technology’s IP rights

We have significantly improved the first draft of the “Radio Protocol” based on extensive R&D activity, flight data and user feedback as well as analysis of extensive internal test results and are continuing to do so. Since the mandatory update of all devices in March 2006 the protocol is in its 5th version, the next version will be implemented in the next mandatory update before March 2008.

Various copyright laws protect our system design. This includes but is not limited to the radio communication protocol, which is highly optimized to our application and is the result of extensive simulation, testing and experience.

Conclusions

We fundamentally believe that our low cost collision warning technology and its licensing procedures are in the best interests of the sport and its participants. We argue that “the FLARM way” is the only cost-effective way to manage and refine such a system and caused it to be its main reason for success. This has also been independently recognized by the OSTIV TSB-panel in June 2006.

Irrespective of our strong believes, we are in principle open to ensuing discussions regarding the future direction of this technology with all stakeholders.

To ensure safety, full compatibility and interoperability are essential. Experience shows that it is impossible to be compatible just by following a written specification. Extensive test case descriptions and simulations are required which must cover every aspect discussed above. It is a huge amount of work to specify these tests and to perform them. Independent bodies would need to be set up governing the process of specification development, testing and certification. This would result in a massive cost increase, ultimately rolled over to the users and furthermore stopping any future innovation. Affordability and the possibility to refine and evolve the system is one of the main elements why FLARM is succeeding so convincingly.

Furthermore we would like to point out that there is an open protocol for positioning reporting and collision avoidance: It has broad governmental and industry support and is specified in RTCA DO-260A (and similar EUROCAE documents) and other publicly available documents, including the whole process governance to manufacture devices. Anyone who prefers the “open standard” approach is free to design and distribute devices based on that open standard.

FLARM is the result of a private initiative and investment. Enormous efforts and risks to overcome sceptical and relevant governing bodies like civil aviation authorities, radio frequency regulators, national aero-clubs and insurance companies have been expended and repeated in every country it is being used. We have supported numerous trials at airfields worldwide and at great expense built a market for a technology that previously did not exist. Our work did not stop there. Today, we are focussing our efforts to allow the technology to transition from a grassroots project into a suitable piece of the worldwide air traffic management puzzle and are founding research by independent institutions to further refine the technology. It is obvious that the duties of representing this technology towards authorities and enlarging its application base can not be carried by every individual manufacturer. We are willing to consider other future licensing and distribution models for the technology developed by FLARM. However, any public distribution of IP is a “one-way street” and therefore every step has to be carefully considered and any change must be reasonable. We are not willing to disclose essential IP without a clear advantage to users and below cost, in addition this would incur great uncertainty and near certain failure with regard to interoperability. Nevertheless, individuals resp. private companies have demanded us to do so, some of which are not willing to understand the technology and workings of FLARM. Now that we have removed all obstacles, a new market has been created which has become attractive for irresponsible companies to crash-land their products into. Furthermore these companies put their customers at risk of devices being confiscated due to IP rights violations.

Rogue devices that attempt to emulate a FLARM signal but are not fully compatible may disrupt communication between FLARM devices for a series of technical reasons. The uncontrollable proliferation of parasitic devices with untested and largely untestable compatibility and performance is undeniably not in the interest of flight safety and thus contrary to our mission.

January 2008, the FLARM Team