# Piccolo Development History

# 1 Introduction

This document outlines a brief developmental history of the Piccolo Autopilot.

# 2 Initial Development

## 2.1 Background

Cloud Cap Technology was founded in 1999 with the primary goal of developing an avionics system for small unmanned aerial vehicles (UAVs). Founders Ross Hoag and Bill Vaglienti were veterans of the Aerosonde UAV development program (1994-1998) and planned to develop a generic avionics system that addressed the shortcomings of the system used in the Aerosonde. The avionics systems concept evolved for the first two years of the company's existence until a core set of Piccolo Autopilot requirements were worked out:

- Although big UAVs were all the rage, eventually it would be the small vehicle that mattered most. Accordingly, the avionics system had to be small, low cost, and low power.
- In order to serve as big a market as possible the avionics system had to be customizable by airframe integrators to work with a wide variety of air vehicles.
- Enough processing power had to be included to allow the system complexity and performance to grow over time to meet new and unanticipated requirements.
- A full three axis sensor set was required in anticipation of sophisticated applications that would require full system state estimation.
- In order to appeal to as broad a customer base as possible a datalink system had to be included so that integrators could quickly get to first flight.
- System interfaces had to be open and accessible to allow third party developers to work with the avionics system. This included the electro-mechanical interfaces as well as software and communications interfaces.
- Hardware in the loop simulation had to be designed in from the beginning to facilitate system test, vehicle design, and operator training.

In the fall of 2001 all of these requirements came together to produce the first Piccolo avionics system and ground station. Piccolo refers to "a small instrument an octave higher than others"; a fitting description of our new autopilot.

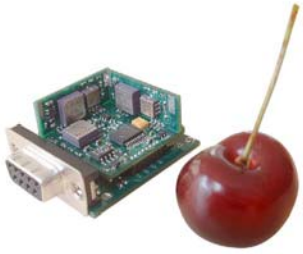
## 2.2 Early Fixed Wing Development

Before the first flight of the new system, but after prototypes were in hand, Cloud Cap was awarded an SBIR from the Office of Naval Research for development of a low cost avionics system. Since basic development had already been completed the contract was re-negotiated to perform initial integration and flight test on ONR's new low cost vehicle, the SWARM (which eventually became the SilverFox). Initial demand for the system was so high that the first ten units, which were never intended for anything but in-house testing, were eventually all sold to customers. Indeed, to this day serial number 1 remains in the field as a simulation and training platform at a university!

Since that time the system has evolved into an exceptionally capable fixed wing avionics system, capable of autonomous launch, navigation, and landing. It has been used in dozens of platforms ranging in weights from a few pounds to more than a thousand. A year after its introduction more than a hundred units had been shipped. Serial number 600 was shipped in April of 2005, and we are now past serial number 1600 (February 2008). Piccolo has accumulated tens of thousands of hours operating in theater. The Piccolo system has become one of the finest small autopilots available to fixed wing UAV designers and Cloud Cap has become an expert at supporting these designers from initial flight testing to fielding their products in theater.

## 2.3 Piccolo Plus

Any system so complex is subject to numerous compromises, and it was no different with Piccolo. In order to achieve the size requirements, the original system used small "camcorder" rate gyros. These gyros required extremely careful calibration and sophisticated software and hardware compensation. When small MEMs rate gyros became available for automotive applications Cloud Cap jumped at the chance to replace the original gyros. Development was started on the Crista sensor head and IMU. At the time of its introduction the Crista IMU was the smallest calibrated and temperature compensated IMU. Shortly after the IMU was released, Piccolo was replaced by Piccolo Plus which uses the Crista sensor head as its inertial sensors. It is completely backwards compatible with Piccolo but provides better performance and allows higher aircraft dynamics. Despite the increased performance Piccolo Plus was priced the same as Piccolo. This ever-increasing performance without cost increase has been a theme of development work at Cloud Cap and many customers have come to appreciate it.



## 2.4 Rotary Wing Applications and Piccolo II

In the summer of 2004 Cloud Cap was approached by the Naval Research Laboratory (NRL) for help in the development of an integrated helicopter autopilot system. Existing solutions were too proprietary, too expensive, and too big. NRL wanted the Piccolo concept, but they wanted it to fly helicopters. Hence Piccolo II was born. Piccolo II includes the extra sensors required to sense and control the state of a free inertial system like a helicopter: extra IO for a magnetometer, a sonic altimeter, Iridium satellite modem, and a 4Hz GPS.

Rotary wing development continued during 2004 culminating in numerous completely autonomous helicopter flights that included launch, waypoint navigation, and landing. Piccolo II also supports fixed wing platforms and is backwards compatible with Piccolo Plus. The new IO features are included on a new connector, and the old interface is still available. Piccolo II also fits in the same enclosure as Piccolo Plus and Piccolo.

## 2.5 Genesis of the Piccolo LT


Despite the small size of the Piccolo system there was still a need for a smaller system. Many new small UAVs built around electric motors are being developed. They have the same needs as their larger brethren: a capable, fully integrated avionics system. Cloud Cap's answer is a smaller and lighter version of Piccolo, called Piccolo LT. Piccolo LT was introduced in August of 2006. It is dramatically smaller than Piccolo and is explicitly designed for these small vehicles. The tradeoff for the smaller size is reduced flexibility; Piccolo LT does not have as much IO capability and it uses a less capable data link. However it still has all the other features that have made the Piccolo platforms so successful.

# 3 Advanced Developments

## 3.1 Version Two Software

First flight of the Piccolo autopilot occurred in spring of 2002. From then until mid-2007 many software improvements were implemented and the system capability grew in an evolutionary fashion to accommodate customer requirements. However after 5 years and 16 software release cycles the initial software architecture was tapped out; engineering new capabilities into the system while maintaining backwards compatibility was becoming impossible.

In anticipation of this Cloud Cap began development of version two of the software in late 2006. Version two was not backwards compatible and was a ground up rewrite of the autopilot firmware, the communications protocol, and the user interface. The goals of version two were many:

- Allow development of advanced control features such as rolling takeoff and landing.
- Increase control performance; allowing precision control for things like recovery into small nets.
- Allow wholesale replacement of one controller for another, i.e. a fixed wing controller, a helicopter controller, a blimp controller, etc. All without having to change the surrounding autopilot software infrastructure, communications specification, or user interface.
- Take advantage of true GPS/INS capabilities – both for control as well as downlink, hence the entire vehicle system state is available on every autopilot cycle.

- The development of a new user interface that was radically superior in terms of its usability and capability; particularly with respect to 3-D mapping.

In mid 2007 the first version two software releases became available and Piccolo performance leaped to a new level. We quickly demonstrated precision control, autonomous precision wheeled landing and takeoff, and many other advanced features. The transition was challenging (customers are never happy when backwards compatibility is broken) and we support many customers using both the old and new generations of software.

## 3.2 Precision Navigation and Recovery

About the time that version two software was being developed the autopilot was generating significant numbers of hours in diverse environments in daily operation. Customers were happy; but now the cost of operations needed to be reduced which meant that the need for operators and pilots had to be reduced. The existing autonomous landing features were good enough for small belly landed airplanes, but their was a rising demand for more advanced precision recovery for:

- Landing heavy vehicles (300+ pounds) on wheels, with a gentle touchdown.
- Hitting a small stationary net.
- Hitting a moving net for recovery onboard a ship.

Accordingly Cloud Cap integrated a dual frequency GPS system capable of relative real-time-kinematic (RTK) performance. With this hardware in place the vehicle can determine is position, relative to the groundstation, to within a few centimeters. In combination with the version two advanced control laws the precision GPS systems allow reliable recovery into fixed or moving nets.

For cases where a large runway is available the RTK GPS system can be replaced with a laser rangefinder used to determine the distance to the ground. This gives the ability to softly touchdown large wheeled vehicles even without the RTK system.

## 3.3 Rotary Wing

Our initial foray into rotary wing development, while successful, did not yield a generally available product. The rotary wing software was heavily customized to the specific platform it was developed for and was encumbered by intellectual property that made it unavailable for non-government customers. All of that changed at the end of 2007 when Cloud Cap officially partnered with Guided Systems Technology (GST), a Georgia company specializing in rotary wing control methodologies. The partnership provides Cloud Cap with key experience in the rotor wing market, as well as access to the IP needed to fully realize a commercially available piccolo helicopter autopilot. In exchange GST gained access to one of the best UAV autopilots on the market.