The Preliminary Incident Report of Yak-54 Flight Test at 13-March-2008

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March 13, 2008
Incident: Yak-54 crashed during a landing approach in a Piccolo II autopilot system flight test activity.

Date: 13-Mar-2008
Time: 07:30am ~ 10:30am
Place: Mike Foley air field
Pilot: Lance Holly
Pilot Assistant: Bill Donovan
Flight Test Engineer: Rylan Jager, Edmond Leong
Safety Officer: Shahriar Keshmiri

1 SUMMARY

In the 7:30am morning at March 13, 2008, a Yak-54 flight test with the Piccolo II autopilot system was ready to perform at the Mike Foley air field for the purpose of control loop system verification. Three flight tests were totally conducted. During a landing approach at the third flight test, within about a foot above the ground, the aircraft engine RPM suddenly went up and turned the aircraft to a nose down position. The aircraft heavily hit on the ground. The landing gear was torn out from the fuselage and the aircraft crash landed on the ground.

It is concluded that the cause of crash was due to a three seconds complete drop out of communication link when the aircraft was about to touch down. This long drop out time triggered the autopilot mode to ON (as the “comm time out” was set at 2 seconds), that drove the throttle position up in order to catch the trim speed. As a result, it turned the aircraft in a nose down position and immediately dived into the ground.

After examining the flight test data, more signal drop out cases were found from all three flight tests. Most drop out times lasted between 0.5 to 1.5 seconds.

In conclusion, it is not recommend to continue using the Piccolo II autopilot system for the Meridan program.
2 OBSERVATION FROM FLIGHT TEST

At March 13, 2008, a Yak-54 flight test with the Piccolo II autopilot system was ready to conduct at the Mike Foley airfield at 7:30am. The objective of this flight test plan was to test the heading control loop and the longitudinal control loop performance and tuned the control gains if it is needed.

2.1 Taxi Test

As required per the check list, a taxi test on the ground was first conducted to verify the RSSI signal. The result of the RSSI check showed a consistent -71 dBm signal (max) at all the time except for few seconds where the signal dropped from -71 to -79 dBm, which is still in the acceptable range of the signal strength.

![Figure 1 RSSI Signal Check from the Taxi Test](image)

2.2 First Flight Test

As the RSSI check passed the requirement, the team was ready to perform the flight test. The first flight test was to test the heading angle control loop performance.

Yak-54 took off at about 8:47am for the first flight test. Test points were conducted according to the dance card procedure. Everything went well during the test. At about 14 minutes, when all the required test points were completed, pilot reported that a loss of aircraft control was notified. So the pilot decided to aboard the mission and landed the aircraft. The aircraft was safely landed and the RSSI signal was checked in response to the pilot concerns.
As shown in Figure 2, the RSSI data seemed normal in most of the time except that there were two signals drop to -108 dBm.

The data were then closely examined to find out when the signal drop out was occurred. Based on the time when pilot reported the loss of control, the first checked was started at the middle times of the data. Later, two signal drop out were seen beginning from 792 seconds. The first drop out lasted for about 0.5 second. The signal was back for a very short time and then went out for another second before it was back to normal again. The finding of this drop out was presented to the pilot and the pilot assistant as shown below.

![Figure 2. RSSI Signal Check from the 1st Flight](image1)

![Figure 3. Close Look of RSSI Signal Data from 1st Flight Test](image2)
After discussed with the pilot and pilot assistant, it was agreed that this signal drop out
might be the drop out that was notified by the pilot. This kind of signal drop out has been
seen before in other flight test data. At the discussion, it was concluded that it was
acceptable to continue the flight test with this noticeable communication issue as this
temporary loss of control was manageable, which has been proven in previous flight tests.

2.3 Second Flight Test
The aircraft was then refueled for more gasoline and then took off for the second flight
test at about 9:21am. The second flight test was to tune the gains for the airspeed control
loop. After fifteen minutes of flight limit times, the aircraft was landed for another refuel
of gasoline. The flight test data were processed to examine the performance of the
airspeed control loop.

2.4 Third Flight Test
The aircraft was refueled again and was ready to conduct the third flight. This flight test
was to continue the previous flight test mission. Aircraft took off at about 10:00am.

During this flight, pilot has reported twice the loss of control. Pilot was always able to get
back the control after the temporary loss of control. The flight test was continued. After
finishing all the required test points, pilot was ready to land the aircraft.

The landing approach was at normal speed and altitude as it was in the last two landings.
However, when the aircraft was about a foot above the ground, a very noticeable sound
from the engine was heard that the engine was trying to speed up suddenly for some
unknown reason. As a result, it turned the aircraft in a pitch down position that led the
aircraft hit the ground heavily. The landing gear was immediately torn out from the
fuselage. The propeller was broken when hit the ground and the engine stalled. The
aircraft crash landed on the ground with the wings on the fuselage about 100 feet away
from the flight test crew.
According to the pilot statement, the engine speed up action was driven by the autopilot system itself, not from the pilot command. The flight test data were immediately checked. It was found that in the last few seconds before the aircraft touched down, a three seconds communication drop out occurred in that critical moment. Since this signal drop out time is longer than the “comm time out” setting (2 seconds as set by the users), the system switched to autopilot mode and attempted to maintain the aircraft in trim condition. Because of this, the system commanded to increase the throttle to increase the trim speed. As a result, it dived into the ground.

A post flight inspection was also conducted on the aircraft to examine the connection of the antenna. The connection still stayed in place. In fact, the system was still transmitting signal with the RSSI signal shown at -71 dBm after the crash. Therefore, it is confirmed that the loss of signal was not due to a bad antenna connection, as happened in the previous incident of Yak-54.

The data plots of altitude, RSSI and engine data as presented in Figure 4 shows the aircraft status when the crash happened. Note that the engine RPM data was zero when the communication signal was back. So the crash happened during the time when the communication link was completely gone.

At this point, it was concluded that the crash of Yak-54 was caused by the loss of communication link in the final critical moment during landing.
Figure 4. Flight Data on Landing Approach from 3rd Flight Test

3 OBSERVATION FROM DATA EXAMINATION

After the incident, all the flight test data were examined closely in order to investigate the cause of the communication problem.

When checking the first flight test data again, another long signal drop out was found. The drop out time was about 2.5 seconds as shown in Figure 5.
From the second flight test data, a communication drop out was observed as well. The drop out time for this case was about three seconds as shown below.

From Figure 5 and Figure 6, it shows the longest signal drop out time that was found from the 1st and 2nd flight. In fact, more than one drop out were seen in each flight. From the third flight test data, about ten times of complete signal drop out were seen when closely examined the data. In most cases, the drop out time were between 0.5 to 1.5 seconds. As shown in Figure 7, the communication suddenly went away when the last value of RSSI was shown at -79 dBm. Then it was back to -79 dBm again and then cycled the drop out activity again for two more times. In this period of time, the RSSI signal kept showing an acceptable value at -79 dBm. So the drop out of signal is almost unnoticeable by the users during the flight test.
4 CONCLUSIONS

Based on the evidences have been seen from the flight test data, it was concluded that the crash of Yak-54 was caused by the three seconds complete loss of communication link during the landing approach. It was assured that the autopilot mode was triggered to active as a very noticeable sound from the engine was observed.

After closely examining all the flight test data, it was found that the signal drop out activity existed in each flight for many times. In most cases, the drop out times were between 0.5 to 1.5 seconds. A drop out time longer than 2 seconds was also seen once in each individual flight test. In the whole flight test, four noticeable loss of control (drop out) were reported by the pilot.

As seen from the data, the signal drop out was not related to any hard maneuver such as deep bank angle turn. It happed in a random base that the signal could completely went away for few seconds even though the last data point was still showing the best RSSI value. Then the signal was back to normal. This unnoticeable sign makes it difficult for the users to monitor the communication status. It becomes more noticeable only when the drop out time lasts long enough that affects the pilot control, as reported by the pilot in this flight test. It is important to know that pilot didn’t report any noticeable loss of control in all previous flight tests since the very last crash of Yak-54 happened.
The 2.4GHz Microhard radio module used on the Piccolo was advertised to provide a transmission range up to 20 miles. In this flight test activity, the operational range was less than 2000 feet. As seen from the data, a complete signal drop out could happen within few hundreds feet distance. Therefore, it was also concluded that the communication problem in this incident was not due to the lack of transmission power. One of the possible reasons could be the limit of the data rate given by the Microhard radio system, or other hardware or software problems in the system.

To sum up, using the communication system provided with the Piccolo II autopilot system, the chance of having a complete drop out of communication link is unpredictable and unavoidable.

5 RECOMMENDATIONS
The random loss of communication link is totally unpredictable and unavoidable by any means even operate in a small range such as this flight test. As shown in all previous flight tests experience, a very short signal drop out time in the air may not significantly affect the pilot control, or the pilot may not even notice the loss of control. A long signal drop out time in the air may also be manageable by the recover action of the autopilot system. However, when it comes to the most critical timing in the landing approach, as occurred in this incident, the consequence of losing the link even for a second will become unmanageable.

The only solution to solve this communication problem is to redesign the whole Piccolo system with a higher reliable communication system, which is way beyond the scope of this research objective. As have been proved by all incidents, the Piccolo autopilot system is not designed to give a reliable performance.
No redundant design was even considered and implemented in this Piccolo autopilot system. Therefore, any signal failure of the system could immediately cause a catastrophic failure of the UAV.

If the Piccolo system is continued to use on another Yak-54 or other aircraft platforms, it is almost inevitable that another major incident would happen again as a matter of time.

Based on my knowledge and experience from the past two years research experience on the Piccolo autopilot system, using the Piccolo system on the Meridan program is highly NOT recommended. As the performance of the system is highly uncertain, and the chance of a system failure is numerous and unpredictable, the risk to the flight test program is extremely high. And the consequence of failure in the Meridian flight test would be unimaginable.