Strato Flight Report

Flight 9

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Flight Date: February 15, 2014

MICHIGAN EXPLORATION LABORATORY

Rev	Date	Notes
1	February 15th, 1014	Initial Release
2	February 18th, 2014	Updated results and analysis
3	March 13th, 2014	Updated formatting and final release
4	May 28th, 2014	Uploaded flight plan

1 Flight Statistics and Information

Launch Location	Harper Creek High School, Battle Creek Michigan
Launch Time	11:40 am
Ground Conditions	Sunny and cold, very little wind
Balloon Size	2000g
Total Mass	about 12 lbs
Launch Notes	Combined operations with M-Burst, filmed by quadcopter

Experiment 1	Epson IMU
Result	Failed to collect data due to unexpected power cycling issue
Experiment 2	Momentum Wheel
Result	Collected gyro data shows some effect of the wheel on payload dynamics

Retrieval Location	NW of Adrian
Retrieval Time	Early Afternoon
Retrieval Notes	Easy retrieval despite significant snow cover
Max Altitude	80,838 ft
Target Ascent Rate	6 m/s
Average Ascent Rate	7.87 m/s
Average Descent Rate	16.76 m/s

Other notes: Launch and retrieval went smoothly due to good conditions on the ground. Max altitude was lower than expected. Of interest is that the balloon did not shred itself as usual. It has a large tear but is otherwise entirely intact.

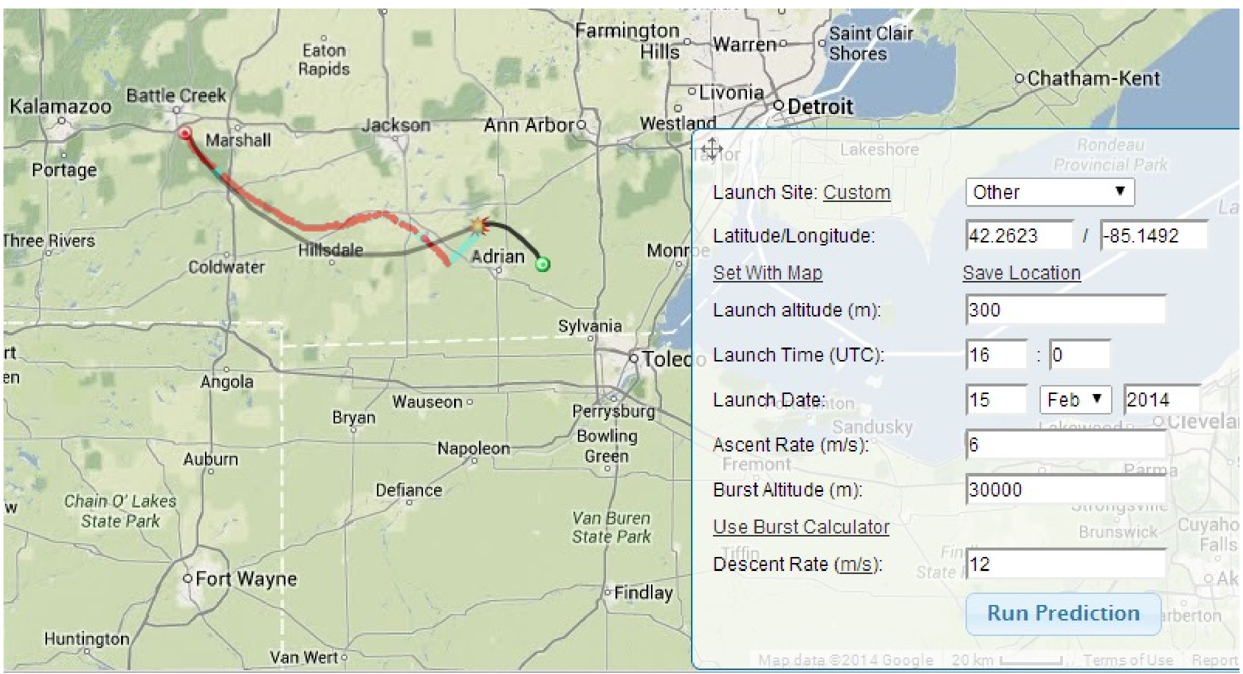

Figure 1: Predicted vs. actual flight path

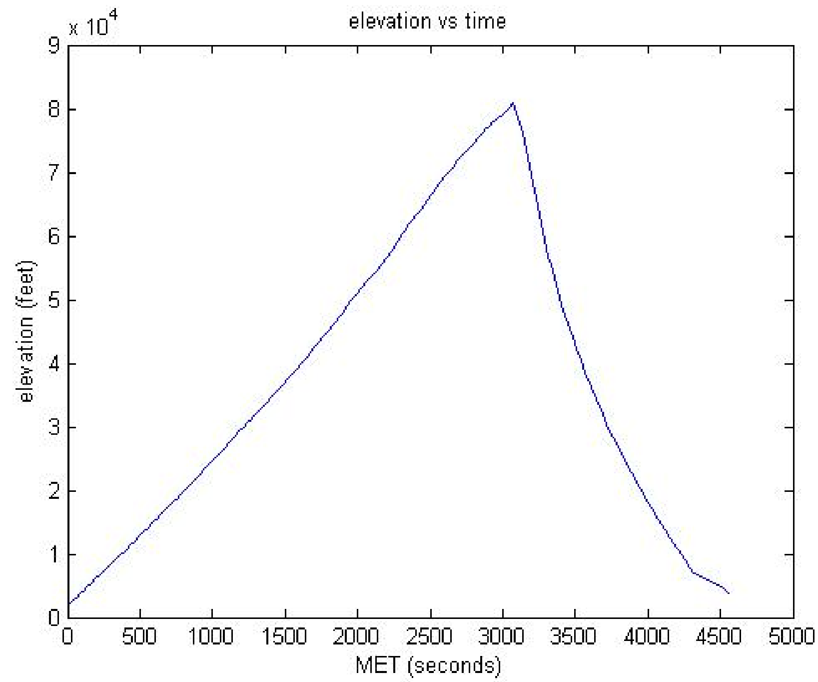

Figure 2: Flight 9 elevation plot

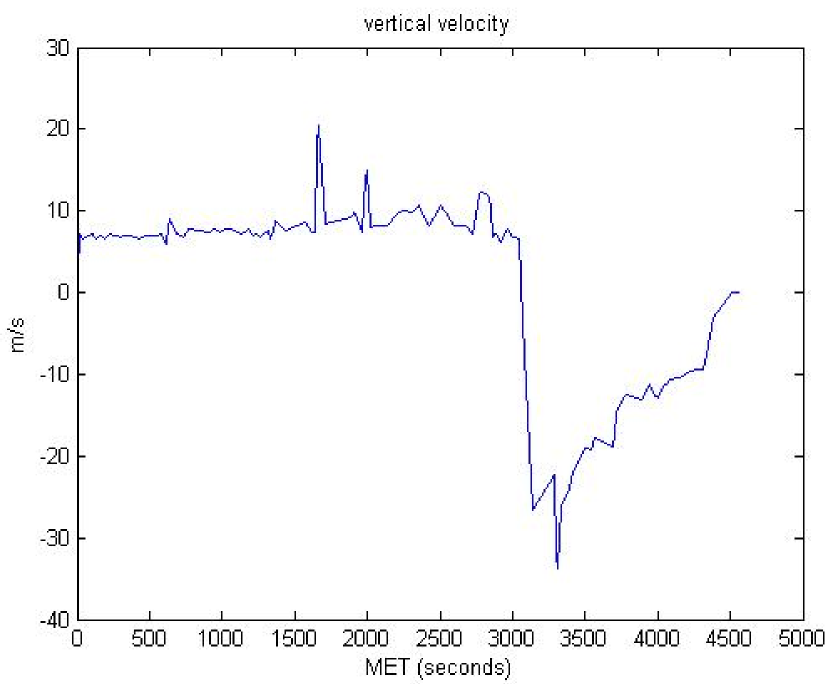

Figure 3: Flight 9 vertical velocity plot

2 Experiment #1: Epson IMU Logging

P.I.	Josh McCready
Purpose	Demonstrate data logging capabilities with the Epsom IMU

2.1 Procedure and Anticipated Results

At the launch site the Pi was turned on and the script was run, indicators LEDs were nominal when they were checked prior to launch. They also indicated that there was power to the IMU and Pi after recovery. Something had clearly gone wrong.

2.2 Hardware Description

IMU	Epson
Processor	Rasperry Pi

2.3 Results and Analysis

After retrieval, a laptop was used to access the data on the Pi. A flash drive was inserted prior to attempting to access the Pi using ssh, and when attempting to recover data from the Pi after launch there was no response from the terminal. That indicated that either the pi was booting or in an inoperable state such as when something is compiling. During integration the pi responded nominally but appears to have lost power lost power prior to launch. This was likely due to a poor battery connector between the regulation protoboard and the pi. After it power cycled the pi stopped logging acceleration and rotation data. When this happens, it is expected that all data would be lost lost and the file to be empty after logging back in and checking it. That was the result during testing on Tuesday and Friday. The data loss should have raised a red flag prior to launch. It is indicative of the lack of robustness in the driver and logging process.

The last bit of data the IMU was able to log is shown in Figure 4, this data can be referenced in the flight data folder.

2.4 Conclusions

1. Data logging the Epson IMU was not successful due to various failures. Steps are being planned to prevent similar occurrences from happening in the future. See Section 2.6

2.5 Next Steps

The Epson will need to be re-flown with upgraded code and infrastructure to prevent the sorts of failures seen on this flight.

2.6 Lessons Learned

1. **The current driver is not robust enough** The implementation that was flown was simple. There was an outfile opened and data was sent to it during each iteration. There was no mechanism that periodically would close the outfile and flush the data buffer to ensure the data was saved at intervals and therefore could be recovered after a power failure. The driver needs to save its data using flush while running. In general to be more fail safe, the needs a mechanism that will restart the script in

the event of the power failure. This could be accomplished using the append method of writing to files and implementing the driver on startup. That way if the power system cut out it could resume measurement after the boot period. These mechanisms are not meant to be fixes to a faulty power system but a safeguard against it.

2. **The current method of providing power for the system is inadequate and failure prone.** There needs to be a fixed and static power bus. Failure has become routine in this regard and is absolutely unacceptable. It stems from loose wire connections between batteries, regulation, and systems. This can be addressed temporarily with more preparation, review, and by affixing all power components to the same surface or hardware mount, that way they are less likely to jiggle as the box is assembled. It would be desirable to switch to one of MXL's small 5.0 V Input Regulator breakouts for future voltage regulation. However the ultimate fix is implement a cubesat style EPS bus.

3. **The current method of payload integration is not adequate for component protection.** The orange payload, which is currently being flown with the intention of collecting experimental data regarding Strato's ADCS equipment, does not allow for easy assembly. The camera and wheel are easy to place, and remain tightly secured, but this compromised the placement of the IMU, Pi, battery, and voltage regulation. It was very difficult to access the Pi once it had been plugged in, and Josh required this for operation. A refined foam-cube structure must be developed prior to next launch that is designed to accommodate this ADCS equipment, at the cost of flying cameras. This structure will allow for secure and compartmentalized placement of these critical ADCS components, such as the IMU, Wheel, and Photodiode board.

4. **There is a need for more scrutiny and validation of flight hardware.** Only two people, Andrew T. and Josh M. I were aware of the potential failure and data loss upon a power failure. In the future a preflight review in front of team should be performed to detect and correct potential failure points before launch. This needs to be done potentially a week in advance to provide adequate lead time to fix bugs and improve reliability. Furthermore giving a lead time before systems are flown can make reduce how many decisions are made the day or two days before the flight. As professor Washabaugh says Nothing good happens after 9 p.m.

2.7 Graphics and Figures

Time (ms)	Error Code	Temp	X acc	Y Acc	Z Acc	X Rot	Y Rot	Z rot	GPIO	RX fails
45300	-512	24	-2278	1966	-403	1167	854	-7684	1536	22
45301	-512	24	-2310	1970	-408	1200	873	-7652	1536	22
45302	-512	24	-2341	1972	-407	1221	883	-7635	1536	22
45303	-512	24	-2365	1973	-409	1246	903	-7630	1536	22
45304	-512	24	-2387	1977	-414	1284	916	-7643	1536	22

Figure 4: Recovered IMU data

3 Experiment #2: Momentum Wheel Trial

P.I.	Evan Hilgemann, Josh Synoweic
Purpose	Demonstrate operation of a momentum wheel in flight and study its effect on payload dynamics

3.1 Procedure and Anticipated Results

The wheel was coded as a momentum wheel prior to flight. It was programmed to toggle on and off approximately every five minutes throughout the flight. The wheel speed was expected to be around 9500 rpm but no direct measurement of this was made. The wheel was completely assembled prior to flight and did not require any external connections. Battery power and data logging were provided within the package. The wheel was be mounted in the payload with its axis of rotation perpendicular to the payload train. The x axis was parallel with the payload train. To initialize the wheel in the field, all that needed to be done is turn the power on using an external power switch.

3.2 Hardware Description

Motor	SunnySky X2212 KV980 II Brushless Motor http://www.buddyrc.com/sunnysky-x2212-13-980kv-ii.html
Motor Controller	Electrify SS-45 http://www.rcuniverse.com/magazine/article_display.cfm?article_id=615
Gyro	L3G4200D https://www.sparkfun.com/products/10612
Battery	Tenergy Li-Ion 18650 11.1V 2200mAh Rechargeable Battery Pack w/ PCB Protection http://www.all-battery.com/li-ion18650111v2200mahrechargeablebatterypackwithpcbprotection.aspx?utm_source=shopzilla&utm_medium=GDF&gdftrk=gdfV26767_a_7c354_a_7c1182_a_7c
Processor	MSP430
Logger	OpenLog DEV-09530 https://www.sparkfun.com/products/9530
Rotor	Two hard drive platters and associate mounting hardware
Rotor inertia	approx. 0.0003 kg*m^2

3.3 Results and Analysis

A plot of all three axis of gyro data for the entire flight from launch to landing is shown in Figure 5. The wheel was powered on when the status line is non-zero. The data is broken down in 18 intervals which correspond to when the wheel was turned on and off. The balloon burst at about 3300 seconds into flight, or just after Section 12. It should be noted that the magnitude of rotation is significant compared to previous collected data. For comparison, a plot of Flight 8 data, which itself was a rather dynamic flight, is shown in Figure 6. The maximum recorded values on that flight were around 100 deg/sec whereas Flight 9 recorded values around upp to 300 degrees/sec for most of the flight and over 600 deg/sec in the higher elevations. The gyro was calibrated a couple weeks before the flight so sensor accuracy is not in question.

A first glance shows no obvious effect of the momentum wheel on the balloon dynamics but some of the data indicates otherwise. Figure 7 shows the calculated average magnitude of the angular speed for each section denoted in Figure 5. Recall that the z axis is parallel with the axis of rotation and the x axis is parallel with the payload train. Very little can be drawn from the interval numbers above 9, but there is a distinct patter in intervals 2-8 especially on the x-axis. During the intervals in which the wheel was powered on, the odd numbered ones, the magnitude of rotation is noticeably less than the adjacent intervals in which the wheel was off. In the case of interval 3, the difference is up to 50

The standard deviation of the angular speeds is displayed in Figure 9 in a similar manner as previously. Similar conclusions can be made as in the discussion of Figure 7. There is little correlation to be made past segment 9. However, from interval 2-8 there is once again a pattern especially noticeable in the z-axis data. The standard deviation of the measurements is lower during the interval when the wheel was powered on as compared to neighboring "off" intervals. For example, intervals 3, 5, and 7 had standard deviations of about 50, 15, and 30 deg/sec less than the neighboring powered "off" sections. A similar, but less noticeable effect can be seen in the y axis data. This would support the claim that the wheel was able to dampen out rotations slightly as long as the disturbance torques were not too high.

On a final note, in the video taken with the on-board Go-Pro, significant grinding noises can be heard from the momentum wheel. It is unclear how much this effected the experiment, but should obviously be corrected in the future.

3.4 Conclusions

1. Flight 8 experienced disturbance torques that far surpassed any previously measured values.
2. The wheel had some effect on rotation about the x and y axes at lower altitudes where the disturbance torques were less significant.
3. The wheel also had a noticeable effect on the z-axis rotation, as shown by an obvious negative rotation bias when the wheel was powered on.
4. It was shown that current reaction wheel hardware was able to remain operational for an entire flight and survive flight conditions.
5. The current wheel construction has some defects as proven by grinding noises heard in Go-Pro footage.

3.5 Next Steps

It is desired to move from a simple momentum wheel set-up to a reaction wheel set-up so pointing can be achieved. Experimentation will be done in the near future on the lab's single axis air bearing to objectively measure the effectiveness of the current set-up. A decision on whether or not a new wheel should be built can be made from that data.

3.6 Lessons Learned and Future improvements

1. There are still issues with timing on the platform. It became necessary to basically guess and check a couple of parameters to achieve a desireable sampling interval. Given, this was an improvement over Flight 8 but implementation of an RTC would solve a lot of issues on that front.
2. In the future, it may be beneficial to include a clock of some sort in the field of view of the Go-Pro footage. This would help correlate audio/visual data with experiment results.

3.7 Graphics and Figures

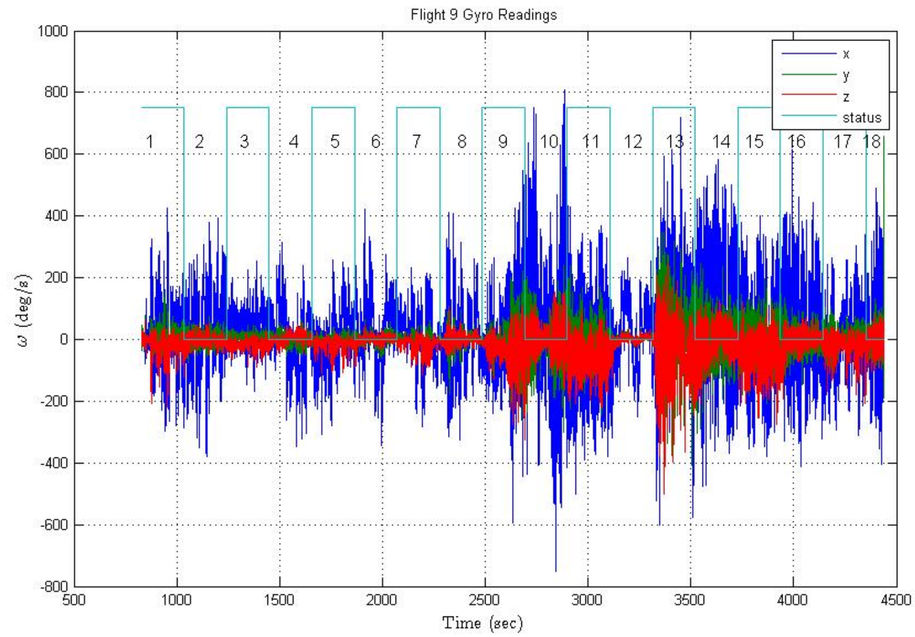

Figure 5: Complete flight gyro readings with intervals of momentum wheel operation noted

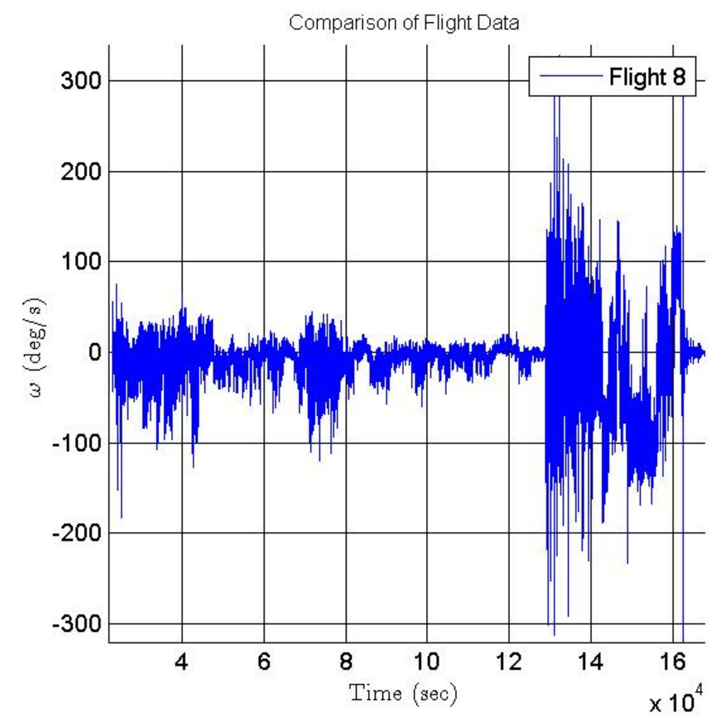

Figure 6: Gyro readings from Flight 8 about the axis defined by the payload train

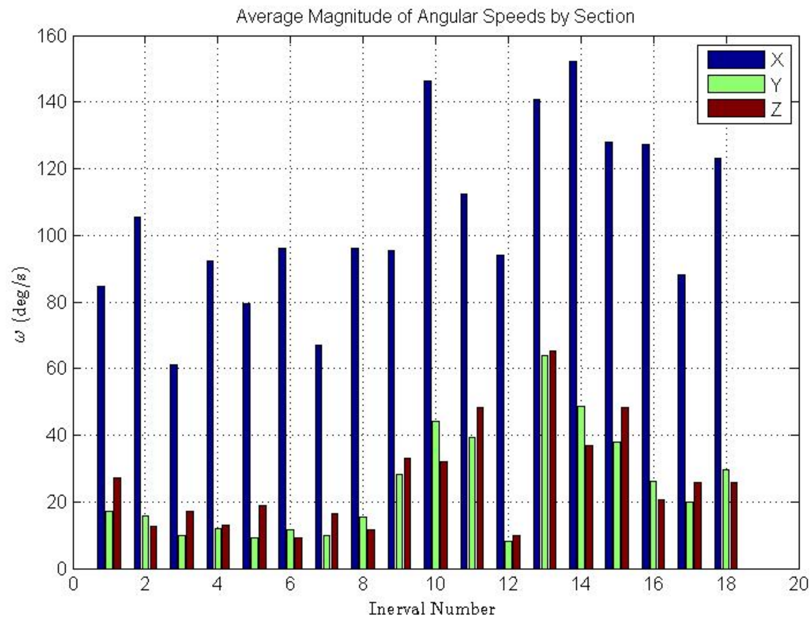

Figure 7: Average magnitude of the recorded angular speed broken down by section

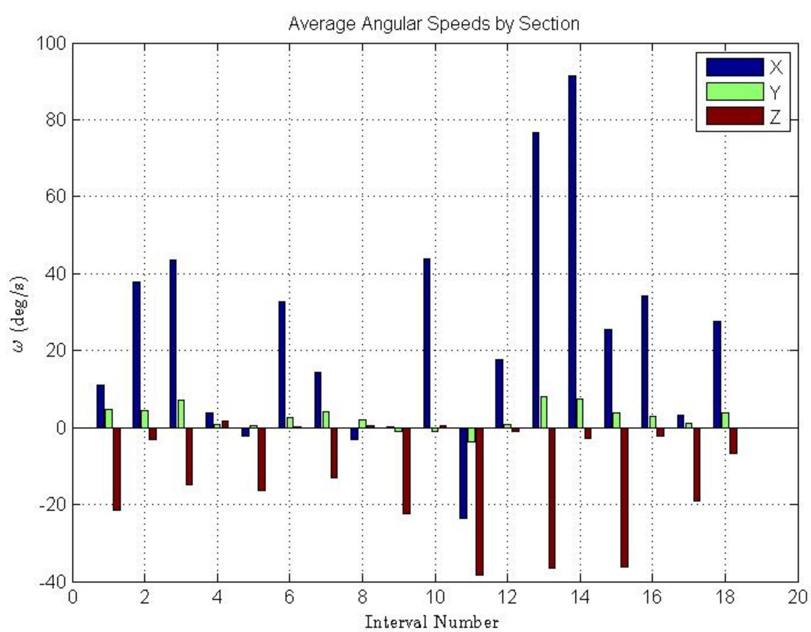

Figure 8: Average recorded angular speed broken down by section

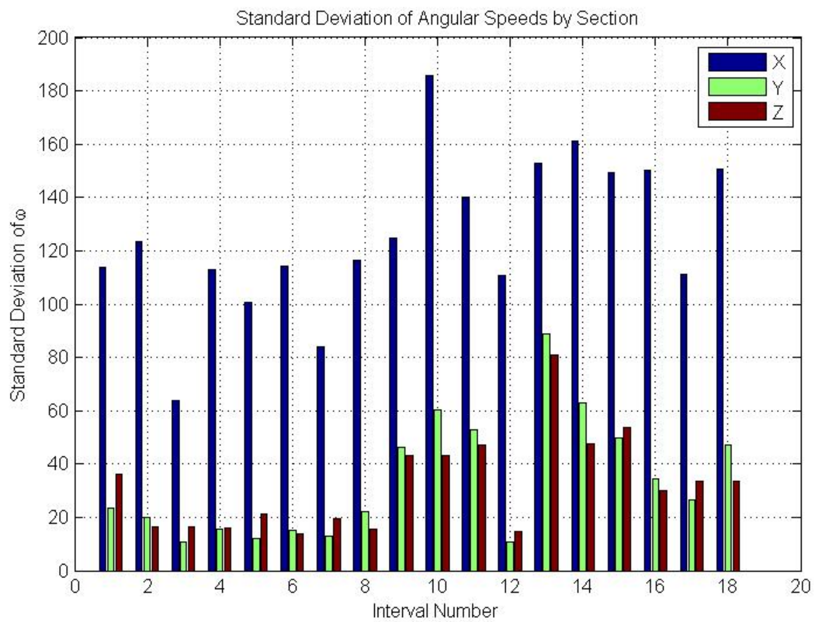

Figure 9: Calculated standard deviation of angular speed, broken down by section

Strato Flight Plan

Flight number:	Date:	Tracking frequency and balloon call signs:
WI4 #2	2/15	KF6RFX-2 -3

PRE-FLIGHT ANALYSIS

Balloon size (g): 2000	Parachute diameter (ft): 6 ft	Estimated burst altitude (ft): 100,000 ft
Package 1 mass (g): (Must be below 2700) 2145	Package 2 mass (g): (Must be below 2700) 1953	Package 3 mass (g): (Must be below 2700) [redacted]
Payload 1 weight/size ratio (oz/in^2): (Must be below 3) 0.99	Payload 2 weight/size ratio (oz/in^2): (Must be below 3) 1.20	Payload 3 weight/size ratio (oz/in^2): (Must be below 3)

Total payload mass (g): (Must be below ~~5400~~ 5444) 5436	Total train mass (g): 7436 with balloon
Calculated neck lift (g): 700	Calculated balloon diameter at launch (ft): —
Calculated ascent rate (ft/min): (Recommended higher than 1000) 1000	Calculated descent rate (ft/min): —

FAA NOTAM filed on (date and time): 2/14	FAA NOTAM filed with (officer initials):	FAA NOTAM filed by (student initials): TM

TRAJECTORY PREDICTION

Launch location (city, state): Kalamazoo, MI	Launch location (VOR radial/nautical miles): BTL 253/09.1 [redacted]	
Landing location (city, state): South of Tecumseh, MI	Landing location (bearing from launch site/distance): 120/54 from launch site	
Total flight time: 2 hours	Predicted launch time (local): 11 am	Predicted landing time (local): 1 pm

INSERT PREDICTION MAP HERE

LAUNCH SITE MEASUREMENTS

Time of departure from FXB (local): 9:00 AM	Time of arrival at launch site (local): 10 AM

Local pressure (~~Pa~~): 29.07 inHg	Local temperature (C): 25.1 °F	Local relative humidity: 38.8 %

Wind intensity:

☐ Light ☒ Moderate ☐ Strong ☐ Gusts

Helium tank 1 initial pressure (psi): 900/1900	Helium tank 2 initial pressure (psi): 1900	Measured neck lift (g): 8.4 kg
Actual launch time (local):	Actual landing time (local):	Actual recovery time (local):