Developing Embedded Control of CubeSat-Based Instrumentation

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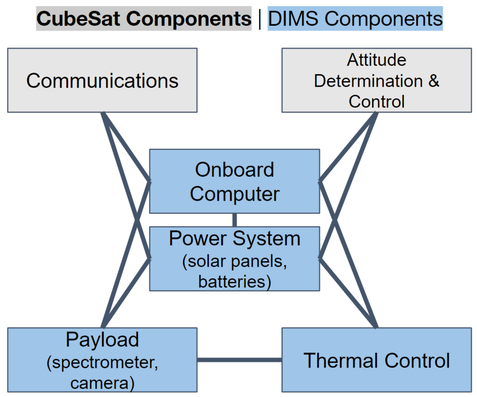
Satellite On-Board Computers

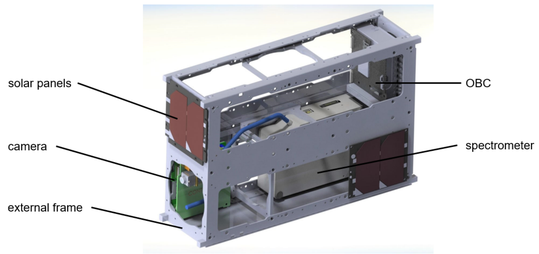
A satellite on-board computer (OBC) is an embedded controller that communicates with other components to carry out tasks. For instance, an OBC may coordinate environmental data acquisition and storage, attitude determination and control, thermal control, and communications with the ground station. CubeSats are small satellites that can be used in coordinated groups for low-cost, distributed environmental monitoring. The Distributed Irradiance Monitoring System (DIMS) is a proof-of-concept for a proposed CubeSat mission, intended to measure total solar irradiance (TSI) from a high-altitude balloon flight. It includes many of the same systems as a CubeSat.



Conceptual Model of CubeSat Components

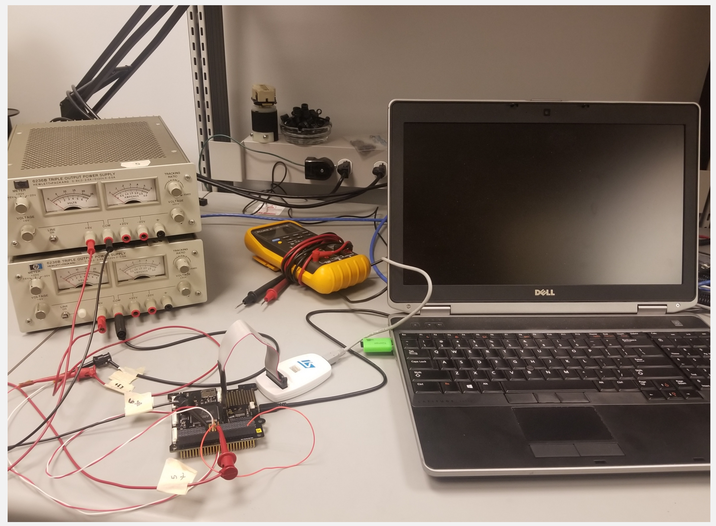
DIMS Computing Requirements

- Read data from sensors
- Automatically create file structure
- Maintain thermal control
- Respond to terminal commands
- Capture images of solar disk



Rendering of DIMS (courtesy of Andrew Carlile)

Software Development Environment



Lab Setup: laptop (with Eclipse IDE), power supply, and OBC

Code Development

Tasks implemented included LED blinking, managing files, reading data from accelerometer and magnetometer sensors, using terminal commands to modify OBC settings, and communicating with an external temperature controller via Serial Peripheral Interface (SPI) protocol.

```
void StartAccelerometer(void const * argument)
{
   AIS328DQ_Init(AIS328DQ_1_MEMS_I2C_ADDRESS)
   HAL_RTC_GetTime(&hrtc, &initTime, calendar_format); //get time of sample
   for(;;)
    {
       fd_result = f_open(&tFil_Temp, "0:/Accel.CSV", FA_WRITE | FA_READ | FA_OPEN_ALWAYS); // Open a file for read/write
       fd_result = f_lseek(&tFil_Temp, f_size(&tFil_Temp)); // Move cursor to the end of the file
       res = AIS328DQ_GetAccAxesRaw(AIS328DQ_1_MEMS_I2C_ADDRESS, &rawOutput); //Get accelerometer data
       HAL_RTC_GetTime(&hrtc, &sTime, calendar_format); //Get time of sample
       fprintf((FILE *)&tFil_Temp, "%2d:%02d:%02d,%i, %i, %i, \r\n", sTime.Hours, sTime.Minutes, sTime.Seconds, output.AXIS_X,
output.AXIS_Y, output.AXIS_Z); //Write data to file
       fd_result = f_close(&tFil_Temp); //Close file
       }
       osDelay(500); //Delay 500ms
    }
}
```

Sample code for accelerometer data acquisition and storage

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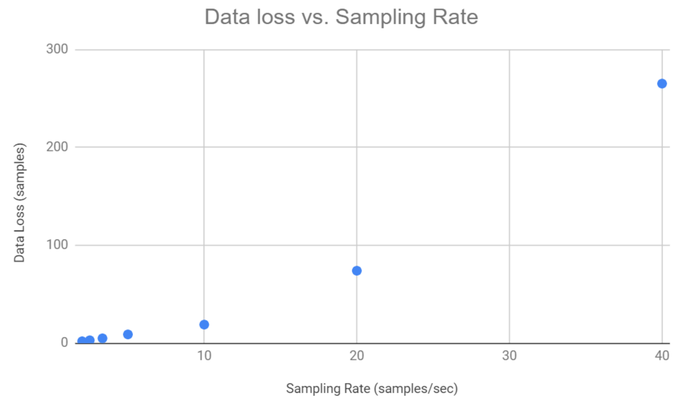
Performance Testing and Results

In order to roughly gauge the computing power of the OBC, a performance test was conducted using file write commands. The accelerometer sampling rate was increased until the number of samples recorded was significantly less than expected, indicating a decline in computing performance. The graph illustrates the difference between the ideal and actual samples recorded in one minute, as a function of sampling rate. It demonstrates that OBC lag increases exponentially, particularly as the sampling rate exceeds 10 samples/second.



Future DIMS Development

- Develop Endurosat OBC Interface with Ocean Optics Spectrometer
- Develop Endurosat OBC Interface with XCAM C3D Camera
- Develop a thermal control system including heaters and PID control to maintain spacecraft subsystems within their operating temperature ranges
- Perform thermal vacuum testing of the spacecraft thermal control system

Acknowledgements

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Reference: "Development and Flight Qualification of a Low Cost Distributed Irradiance Monitoring System" proposal by HAO Instrumentation Group, Spring 2019