

Capstone Senior Design 2018–2019



SPACE COMMUNICATION UTILIZING BACKBONE EXISTING NETWORKS

SCUBEE Detailed Design Review February 2019





Meet the Team



Avery Brock E.E. **Electrical Design Lead** Team Lead

YiYang E.E. **Electrical Design** Budget Manager

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Hunter Kanniainen M.E. Mechanical Design Lead **Client POC**

Tim White M.E. Mechanical Design Secretary





Project Objectives

Objective MIS-1

 The project shall develop the hardware module and software package required to achieve a live network connection from a cube satellite in low earth orbit to a remote ground-based server using the Iridium Core 9523 satellite communication module

Objective MIS-2

 The project shall further develop and optimize the Tube Deployable Reentry Vehicle (TDRV), a three-stage reentry vehicle launched from an orbital payload at the Von Karman altitude





TDRV Mechanical Design





Review of Proposed Improvements

Replace felt material with high strength conductive nylon descent arrestor to improve GPS signal quality. Integrate FM APRS antenna into struts. Shorten struts to reduce drag

Replace railmounted end cap with threaded end cap

Reconstruct interior to accept configurable electronics tray



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Mount GPS and Iridium Antennas to end cap in addition to drop mechanism

Replace 3-D printed body with machined tube; scale larger to allow more room for customization

Introduce threaded nose cap with transparent lens



Descent Arrestor Factor of Safety



- Pin and hard stop approximated as fixed cantilever end
- Maximum shear and moment calculated for respective stresses
- Factor of safety calculated from stresses and yield strength

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Descent Arrestor Bending Stress

Variable	Equation	Value	Unit
Drag Force (Fd)	given	15.5	Lbf
Force on Member (F)	Fd/8	1.95	Lbf
Dist. Load (w)	F per in	1.95	ilbf/in
Length of Strut (L)	given	12.19	In
Width of Strut (b)	given	0.25	iln
Height of Strut (h)	given	0.38	ln
Area of Strut (A)	b*h	0.095	in^2
Max Moment (M)	(w*L^2)/2	144.8811975	ilbf-in
Moment of Inertia (I)	b*h^3/12	0.001143167	′in^4
Dist to NA (yc)	h/2	0.19	In
Max Bending Stress			
(Sigma)	M*yc/I	24079.97742	Psi
Yield Strength (YS)	given	35000	Psi
Factor of Safety (FS)	YS/Sigma	1.453489735	Dim



Main Takeaways:

- Max Bending Stress -= 24079.98 psi
- Yield Strength = 35000 psi
- Factor of Safety = 1.45
- Bending is primary factor -





Descent Arrestor Pin Double Shear Stress

	Din Daubla Shaar	
	Pin Double Shear	
Variable	Equation Value	
Diameter of Pin (D)	aiven	
Force on Member	aiven	
	given	
Shear Stress (tau)	4*F/(2*pi*D^2)	
Yield Strength (YS)	given	
Factor of Safety (ES)	YS/tau	



Unit 0.19In 23.77Lbf

419.2Psi

35000Psi

83.5Dim

Main Takeaways:

- Max Shear Stress = 419.2 psi
- Yield Strength = 35000 psi
- Factor of Safety = 83.5 -
- Shear is minor factor





Model Overview – Nose Cone & Main Assembly



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Model Overview – Body











Model Overview – Strut Ring



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Manufacturing Plan

Order •

- Main Body •
- Strutt Ring
 - Struts
- Nose Cone
- Endcap •







Design Validation Plan

	А	В	с	D
16	MECH-2.1.1	TDRV shall fit within a 12x12x30 inch launcher in collapsed position	Test	Prototype drawing file will be drawn to meet required specifications. Physical protoype shal be measured at local extrema to ensure dimesnion specifications are met.
17	MECH-2.2.1	The TDRV shall be connected to the weather balloon via mounting in a tube release mechanism	Test	An arresting cable shall connect the TDRV to the release tube. The cable will connect via a mounted platter and linear actuator.
18	MECH-2.3.1	TDRV midlevel drop will take place above 100 feet	Test	TDRV will be dropped from kibbie dome camera stand to determine stability of deployment of descent arrestors
19	MECH-2.3.2	TDRV midlevel drops will take place in safe environment such as a bridge over a river to ensure minimal risk to property as failsafe	Test	The devils canyon bridge will provide adaquate height for practical testing
20	MECH-2.3.3	Descent arrestors will deploy upon drop	Test	Fins will inflate automatically under adaquate air pressure and density
21	MECH-2.3.4	TDRV descent velocity shall not exceed 25 mph during drop test	Analysis	Fluids analysis software will be used to determine coefficient of drag to a reasonable precision before physical protoype is constructed
22	MECH-2.3.5	Drop tests shall be done in non vertical angles to ensure ability of arrestors to safely deploy from non-ideal angles	Test	Launch tube will be place at odd angles during bridge tests to simulate non-uniform balloon conditions
23	MECH-2.3.6	TDRV shall successfully deploy arrestors and correct offset orientation 20 times consectively in low level drop tests before moving to mid level drop tests	Analysis	Tests will take place dropping the protoype with minimal electronics to record velocity. Drops will be done from an elevated platform
24	MECH-2.4.1	TDRV shall contain a delayed release parachute descent arrestor mechanism	Test	Tests will be conducted to mimick altitmeter readings to test functionality of drag chute
		A quide percebute shell be released from		Once tube parameters are given, the

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TDRV **Electrical Design**







Block Diagram Version 2.0



TDRV Controller Board

Version 2.0 SCUBEE

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Component Research

Teensy 3.5



MPL3115A2









Copernicus II Module(GPS-11858)













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Component Research Continued

LM1085 (Voltage Regulator)







Tes Bus







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HX1 Radiometrix



Molex

L12-R Mirco Linear Actuator







Current Schematic



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Timeline

DATE		Expectant Result					
2019/2/20		Preliminary Schematic is Completed					
		Simulation and Correct					
2019/2/26		Complete Final Schematic					
2019/3/5	Snapshot day 3	PCB Board Design					
2019/3/15		Wiring					
2019/3/20		PCB Board Test					
2019/3/22		Order Components					
2019/4/1		Review					
2019/4/5		Make TDRV Board					
2019/4/16		Connect with Other Parts					
2019/4/26	Design EXPO						

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Validation Plan Overview

- Preliminary schematic is confirmed
- Most of components are selected
- Ordering links of selected components are • confirmed









Iridium 9523 Development





Revised Boost Converter Simulation Model



Original Input Current	6.3A RMS
New Input Current	3.8A RMS
Original Output Ripple	0.15V
New Output Ripple	0.10V



- Increased Inductor from 22uH ulletto 47uH to compensate for voltage increase Swapped from Tantalum to \bullet **Tantalum-Polymer capacitors** to reduce ESR and ripple Reduced ESR allows for more ulletcapacitance
- Modeled IO signals



Revised Boost Converter Simulation Results







Worst-Case Scenario Test: Cold, Low-battery Satellite



Simulation verifies design specifications will be met

Driver IC	LT3959								
Specification	Minimum	Nominal	Maxim						
Input Voltage	6.8 VDC	7.4VDC	8VD						
Output Voltage	27 VDC	30 VDC	32 V D						
Output Current	0 mA	900 mA	1000 n						



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_	-i	080mA
	-	990mA
	-	900mA
	-	810mA
	-	720mA
	-	630mA
	-	540mA
2000	-	450mA
~	-	360mA
2000	- 1	270mA
2000	-	180mA
	-	90mA
_	-	0mA
		000





Revised Boost Converter Ideal Operation



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Carrier Board Schematic



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Date: 2/1/2019 11:20 PM

Sheet: 1/3



Carrier Board Schematic



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Carrier Board Schematic



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Carrier Board Layout





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PCB Bottom Layers



Full PCB

PCB Top Layers



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Carrier Board 2-D Renders



136 components all rated for near-space 0605 standard package size 22 test points, 15 LEDs, 6 configuration jumpers



Full PCB: 150x70mm RF via stitching along perimeter



Carrier Board 3-D Renders





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Support and Testing Boards

Iridium 9523 Simulator

Designed to test power supplies and IO before use of actual module, 9523 form factor PCB





convert UART to USB for PC debugging



Support and Testing Board Layouts

Iridium 9523 Simulator





TES Bus USB Adapter





Support and Testing Boards 2-D Renders

Iridium 9523 Simulator



73x38mm





TES Bus USB Adapter

52x30mm







Support and Testing Boards 3-D Renders

Iridium 9523 Simulator





TES Bus USB Adapter





Assembly and Testing Process

- All parts, PCBs, and assembly materials have arrived – ready to build
- Build support PCBs first to facilitate carrier PCB testing
- Begin by populating carrier power supplies and LEDs
- Populate boost converter
- Populate SAMD21 and burn Arduino bootloader
- Populate Iridium support components
- Fully test with Iridium simulator before mounting 9523

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Review of Software Design

- 1. Configure modem
- 2. Call Iridium
- 3. Setup PPP connection with Iridium
- 4. Negotiate IP address using PPP
- 5. Create network stack using IP address
- 6. Pipe data between modem and either stdio (rev0) or tdrv (rev1)





Software Library Development

- Revision 0 (Computer)
- Configures Modem
- Calls ISP
- Pipes data
- No PPP connection
- No network stack

- Revision 1 (Microcontroller) Pipes Data
- No configuration No calling No PPP conenction
- No network stack





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NAL Module USB Cable Rebuild



Existing Cable

- No shielding
- No strain relief
- Only three-wire RS-232

New Cable

- Shielding and strain relief
- Power and RF active LEDs
- Full 9-wire RS-232

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train relief ctive LEDs 232





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NAL Module Testing



- Revision 0
- Able to communicate with modem
- Able to dial out (with difficulty)
- Not able to send data

- Revision1 Not yet tested
- wvdial (3rd-party library)
- Detects modem
- Refuses to communicate with modem



Progress:

Successfully established • connection to Iridium Network after determining antenna requires ground plane



Software Development Plan

Now

- rev0: Work on PPP connection
 Snapshot 3
- rev0: Work on network stack
- rev0: Final testing
- rev1: Port to microcontroller
- rev1: Final testing
- Expo





Project Budget

		Project	t Bude	ot										
Project Budget														
Project:				NASA Ame	es-Suborbi	tal Flight (Communica	tion						
Last Updated					02/1	15/2019								
		20	018				2019			Item Total	Total Spent	Actual		
Expense Items	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May					
Inidium (83)														
PCB Carrier Board						\$ 70	<u> </u>			\$ 70				
PCB part(Carrier Board)						\$ 175				\$ 175				
9523 Test PCB						\$ 10	, 			\$ 10				
PCB part (9523 Test PCB)						\$ 20	1			\$ 20				
Test Simulation PCB						\$ 10	1			\$ 10				
PCB part(Test Simulation PCB)						\$ 20	<i>i</i>			\$ 20				
LiPo battery						\$ 60	1			\$ 60				
Flight Control						\$ 50	<u> </u>			\$ 50				
GPS and Iridium Antenna						\$ 50				\$ 50 ¢ 770	Total Spont=			
Iridium Final Test Module					<u> </u>		+			\$ 770	Total spent-			
PCB						\$ 100	, <u> </u>			S 100				
PCB part						\$ 125	1			\$ 125				
										\$ 450				
TDRV(*2)														
PCB						\$ 70	1			\$ 70				
PCB part						\$ 200	/			\$ 200				
										\$ 540	Total Spent=			
Launch(He)						¢ 20				Ć 20				
Parachute fabric						\$ 20	/			\$ 20				
S volt linear actuator						\$ 30				\$ 30				
S voit mean actuator						\$ 50				\$ 130	Total Spent=			
Travel (4)							+			+	roturopent			
Flight(4)								\$ 1,136		\$ 1,136				
Hotel(2 or 3rooms, 2 night)								\$ 440		\$ 440				
Rental Cars								\$ 363		\$ 363				
PerDiems								\$ 854		\$ 854				
Mileage								\$ 23		\$ 23				
Other										\$ -	Total Sponts			
							+			\$ 1,680	Total Spent=			
Moscow High School (\$1000)							+				we can get from last semest	er		
Servos(3)						\$ 150	,			\$ 150	ne can get non nast sentest			
Aduino Uno						\$ 24	i l			\$ 24				
Raspberry Pi 3						\$ 45	i			\$ 45				
Battery Connector						\$ 3	1			\$ 3				
Accelerometer						\$ 14	<i>k</i>			\$ 14				
On/Off Key Switch Lock						\$ 12	<u> </u>			\$ 12				
Membrane Keyboard						5 8				\$ 8				
GPS Radio Tracker						\$ 167	1			\$ 167				
Case Plate(Pi Plates)						\$ 15				\$ 15				
Relay Plate(Pi Plates)						\$ 42				\$ 42				
Shipping Fee(Pi Plates)						\$ 8	1			\$ 8				
										\$ 497	Total Spent=			
Supplies Sent from Ames														
Assembly Bits						e -				¢ -				
Solder: Kester 63/37.031" diameter						\$ 5				\$ 5				
Solder Paste: MG Unemical 63/37 no clean 35g syringe Solder Wick: NTE Electronics SW09-10 #4 blue						\$ 21				\$ 21				
Weller Tip: WESD51 1/32" long conical tip						Ś A	it			Ś A				
Tong content tip							<u> </u>			\$ 36				
									Totals	\$ 4,103		\$ -	\$ (4,103)	
												Budget	Excess	

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Key Events

- NASA Ames Trip 4/17-4/20/19
 - Bring any project materials to facilitate joint testing \bullet
- **Proposed Publications** •
 - IPPW Conference
 - **IEEE NAECON Conference**
 - University of Idaho Engineering Expo •
 - University of Idaho Undergraduate Research \bullet Symposium
 - Seattle Times Article UI Sponsored









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