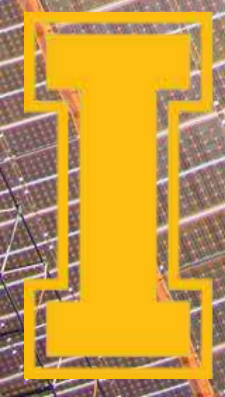




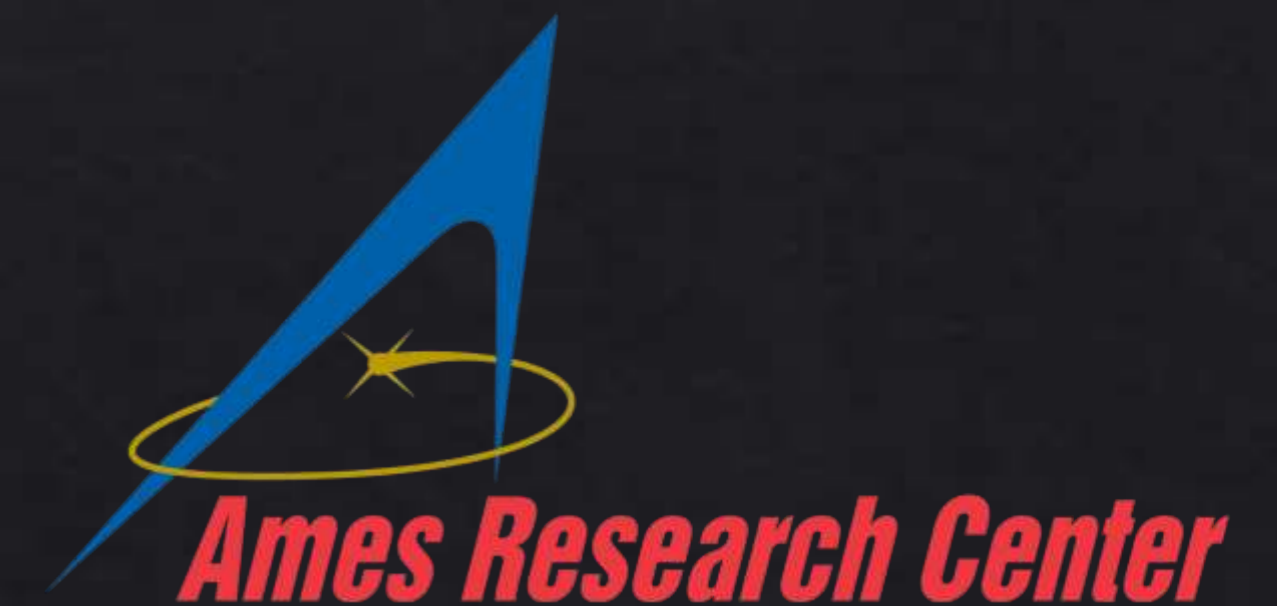
SPACE COMMUNICATION UTILIZING BACKBONE EXISTING NETWORKS

SCUBEE

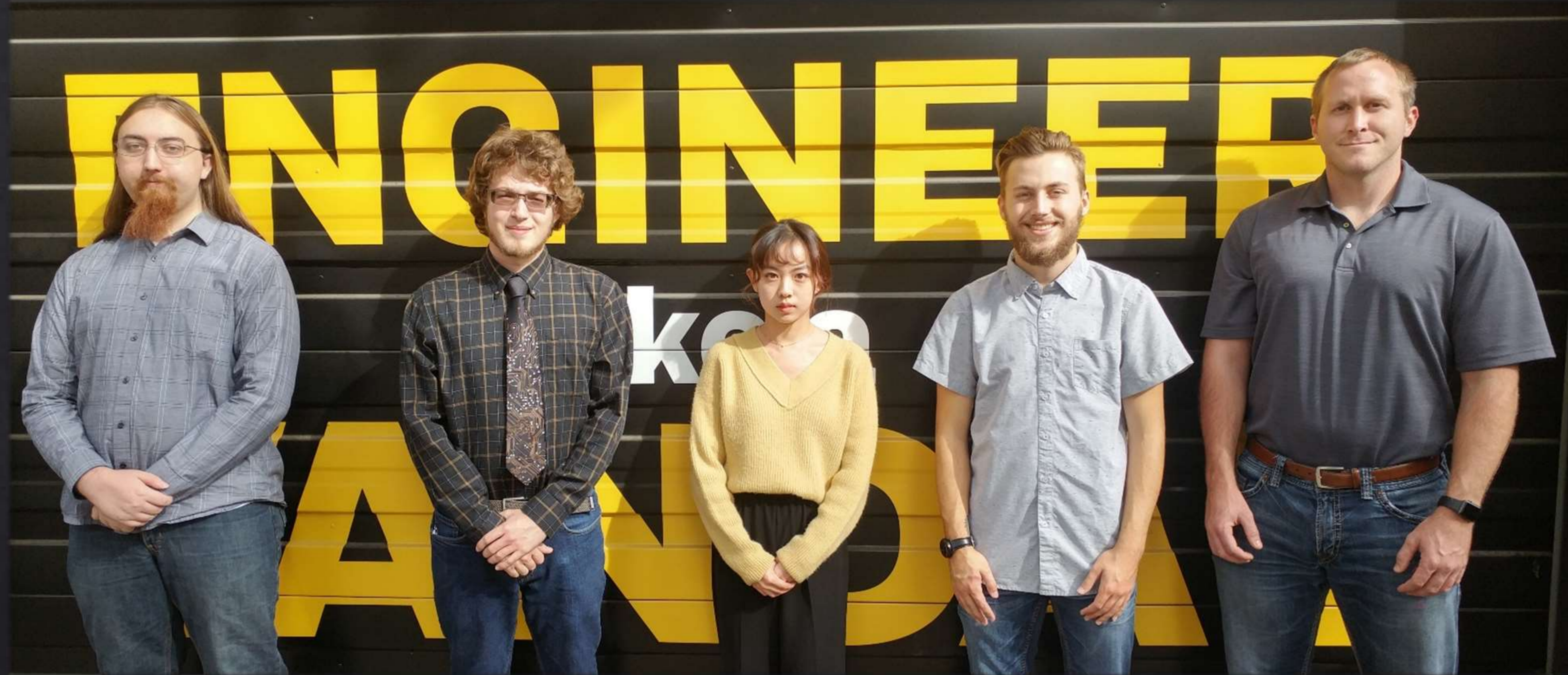
Preliminary Design Review
December 2018



University of Idaho
College of Engineering



Meet the Team



Hunter Barnett
C.S.
Software Design Lead

Avery Brock
E.E.
Electrical Design Lead
Team Lead

Yi Yang
E.E.
Electrical Design
Budget Manager

Hunter Kanninen
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

Project Research

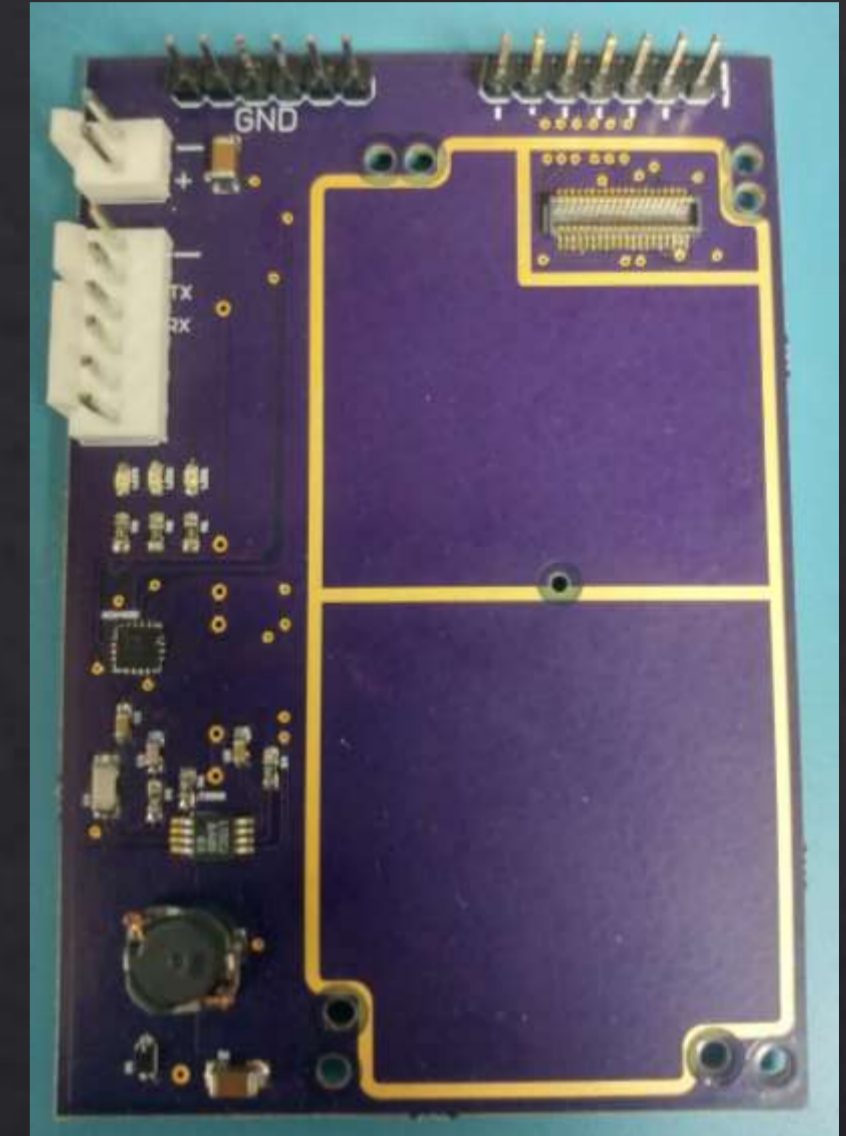
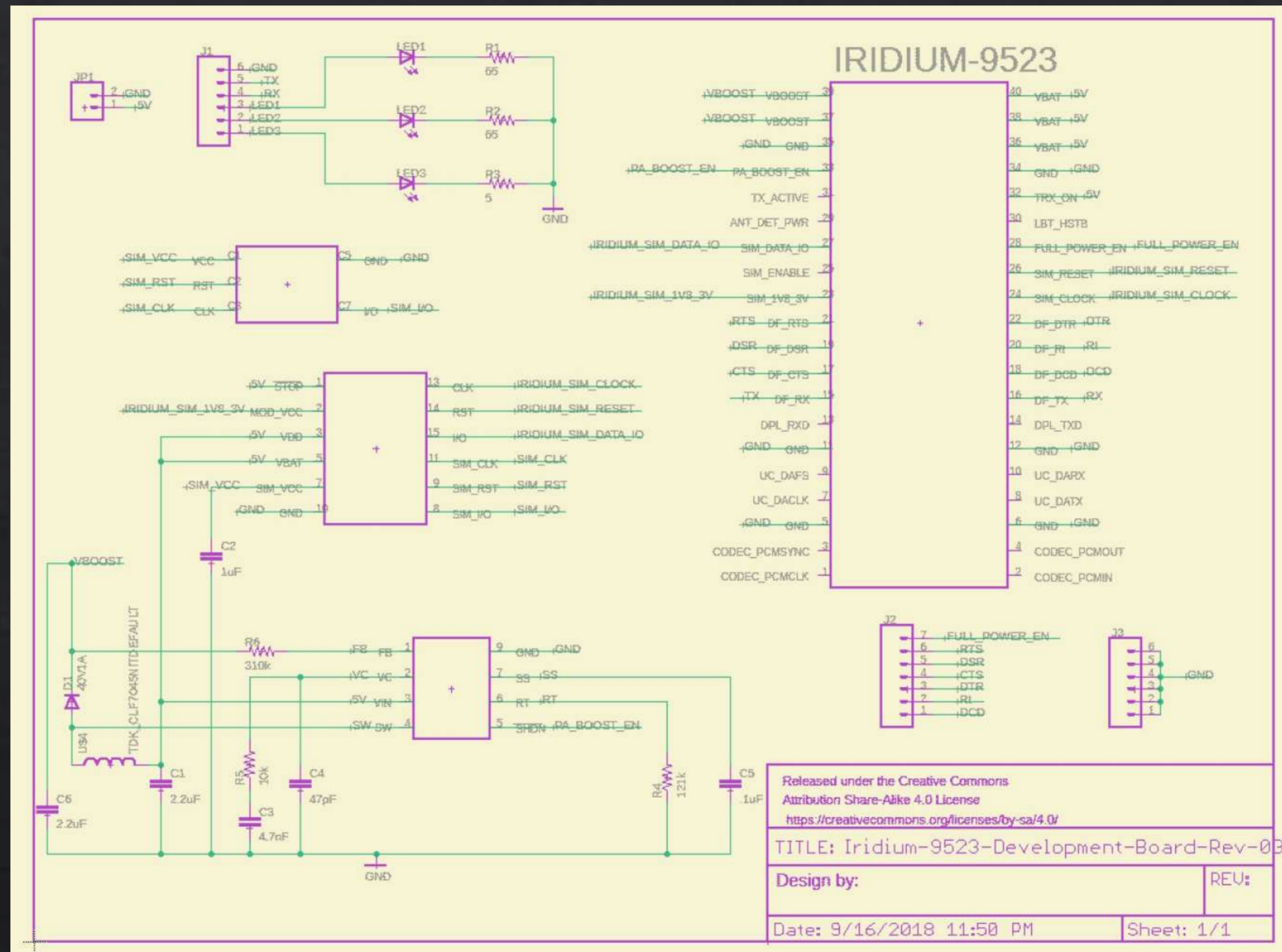
Team Rocket 2016-2017

Team Goals:

- Creation of carrier PCB for Iridium 9523
- Initial development of Arduino library
- Testing of NAL A3LA-RS Iridium module

Results:

- Unable to communicate with 9523 on custom PCB
- Successful communication with NAL module (handshake)
- Unreliable satellite network connection



Team Rocket Schematic and PCB

Team ACOM 2017-2018

Team Goals:

- Develop software for the Raspberry Pi to use the 9523 as a dial-up modem
- Create a remote server to send data to
- Test a ZigBee mesh network
- Create and test fly a prototype TDRV

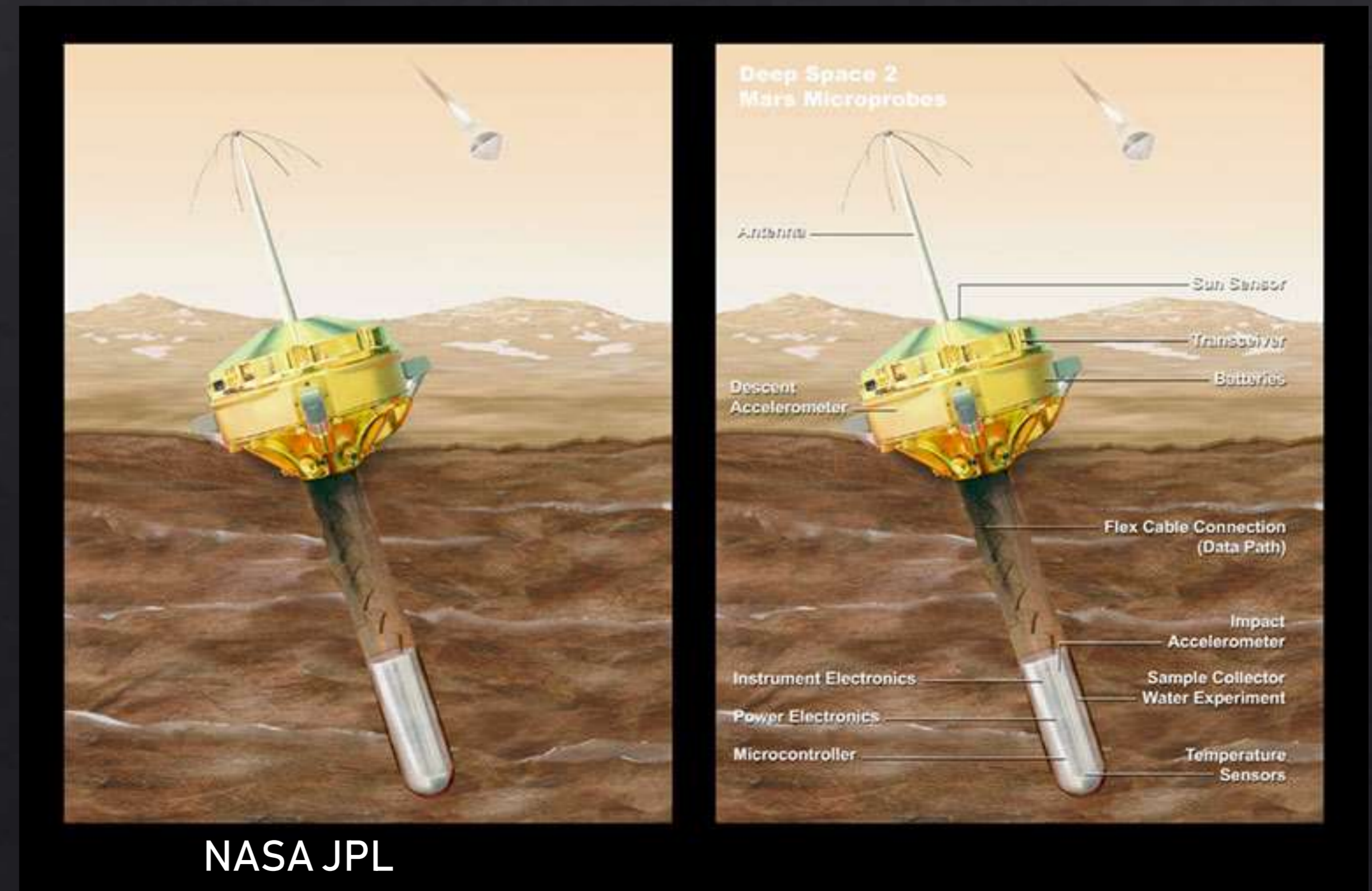
Results:

- Unable to establish dial-up connection
- Initial ZigBee code written, no mesh testing
- Single TDRV test in Kibbie Dome



Deep Space Two

- Purpose:
 - Use a two part probe modeled as the DS2 shape to penetrate the surface of Mars to test the working design for spacecraft landing without a parachute.
- Result:
 - Mission declared failure after no communication with probes could be established.
- Possible Reasons for Failure:
 - Radio/probe destruction upon impact (too rough of terrain)
 - Battery charge failure



Iridium Cores Overview



Iridium® IoT

**Reliable Data Connectivity
for Fixed and Mobile Use.
Absolutely Everywhere.**

Iridium's low-latency Internet-of-Things (IoT) solutions leverage the power of the world's furthest reaching network to extend the high value of intelligent data beyond the barriers of terrestrial networks. Designed to be integrated into end user applications, this range of proven hardware allows partners and customers to quickly utilize Iridium's unrivalled global network to communicate with their assets in virtually any market.

	Iridium 9602	Iridium 9603	Iridium Core 9523	Iridium 9522B	Iridium Edge™
FORM FACTOR	Board-to-Board	Board-to-Board	Board-to-Board	Black Box	IP67 rated
DIMENSIONS	41 x 45 x 13mm	31.5 x 29.6 x 8.1mm	70.44 x 36.04 x 8.9mm (H)	162 x 81 x 28mm	130 x 80 x 30 (H)
INTERFACES	AT + Command	AT + Command	AT + Command	AT + Command, RS 232 Digital/Analogue	RS232 AT command interface On/Off Control lines
POWER REQUIREMENTS	+5 V +/- 0.5 V	+5 V +/- 0.5 V	+3.2 V to +6 V	+4.0 VDC to +32 VDC	Power Supply (9-32V), SAE J1455, Load dump protected Reverse Polarity Protection
POWER CONSUMPTION	Idle 35 mA Transmit 140 mA Receive 40 mA	Idle 34 mA Transmit 145 mA Receive 39 mA	Idle 70 mA Transmit 300 mA Receive 110 mA	Idle 220 mA Transmit 800 mA Receive 800 mA	1.6W (peak for short transmit burst), Low Power Modes: < 200uA
OPERATING TEMP RANGE	-40°C to +85°C	-40°C to +85°C	-30°C to +70°C	-30°C to +70°C	-40°C to +85°C
VIBRATION AND SHOCK	EN60068-2-14:2000 EN 60068-2-36:1996 EN60068-2-27:1993 J1455	EN60068-2-14:2009 IEC60068-2-64: 2008 EN60068-2-27: 2009 SAE J1455	EN60068-2-14:2009 IEC60068-2-64: 2008 EN60068-2-27: 2009 SAE J1455 MILSTD 810	EN60068-2-14:2000 EN60068-2-32:1993 EN60068-2-27:1993 EN 60068-2-6:1996 SAE J1455:1994	SAE J1455 SAE J1555
TYPICAL APPLICATIONS	Personnel and asset tracking, fleet management, environment and safety monitoring, remote automation and control	Personnel and asset tracking, fleet management, environment and safety monitoring, remote automation and control	Maritime, aviation and mobile markets	Maritime, aviation and mobile markets	Asset tracking, fleet management, environment and safety monitoring, remote automation and control
DEVELOPMENT KIT AVAILABLE	YES	YES	YES	N/A	YES
SERVICES	SBD SM , Iridium Burst [®]	SBD SM , Iridium Burst [®]	SBD SM , CSD, SMS, RUDICS, TELEPHONY	SBD SM , CSD, SMS, RUDICS, TELEPHONY	SBD SM , Iridium Burst [®]
AVERAGE LATENCY	<20 seconds per 340 bytes (MO)	<20 seconds per 340 bytes (MO)	<45 seconds for 1KB message (MO and MT)*	<45 seconds for 1KB message (MO and MT)*	<20 seconds per 340 bytes (MO)
MAJOR NETWORK AND REGIONAL CERTIFICATIONS	FCC, IC, RED, CE, Anatel, Australia, RoHS, others	FCC, IC, RED, CE, Anatel, Australia, RoHS, others	FCC, IC, RED, CE, Anatel, Australia, RoHS, others	FCC, IC, RED, CE, Anatel, Australia, RoHS, others	Iridium [®] satellite network certification, FCC, IC, RED, CE, Anatel, Australia, RoHS

Iridium 9523 Core Overview

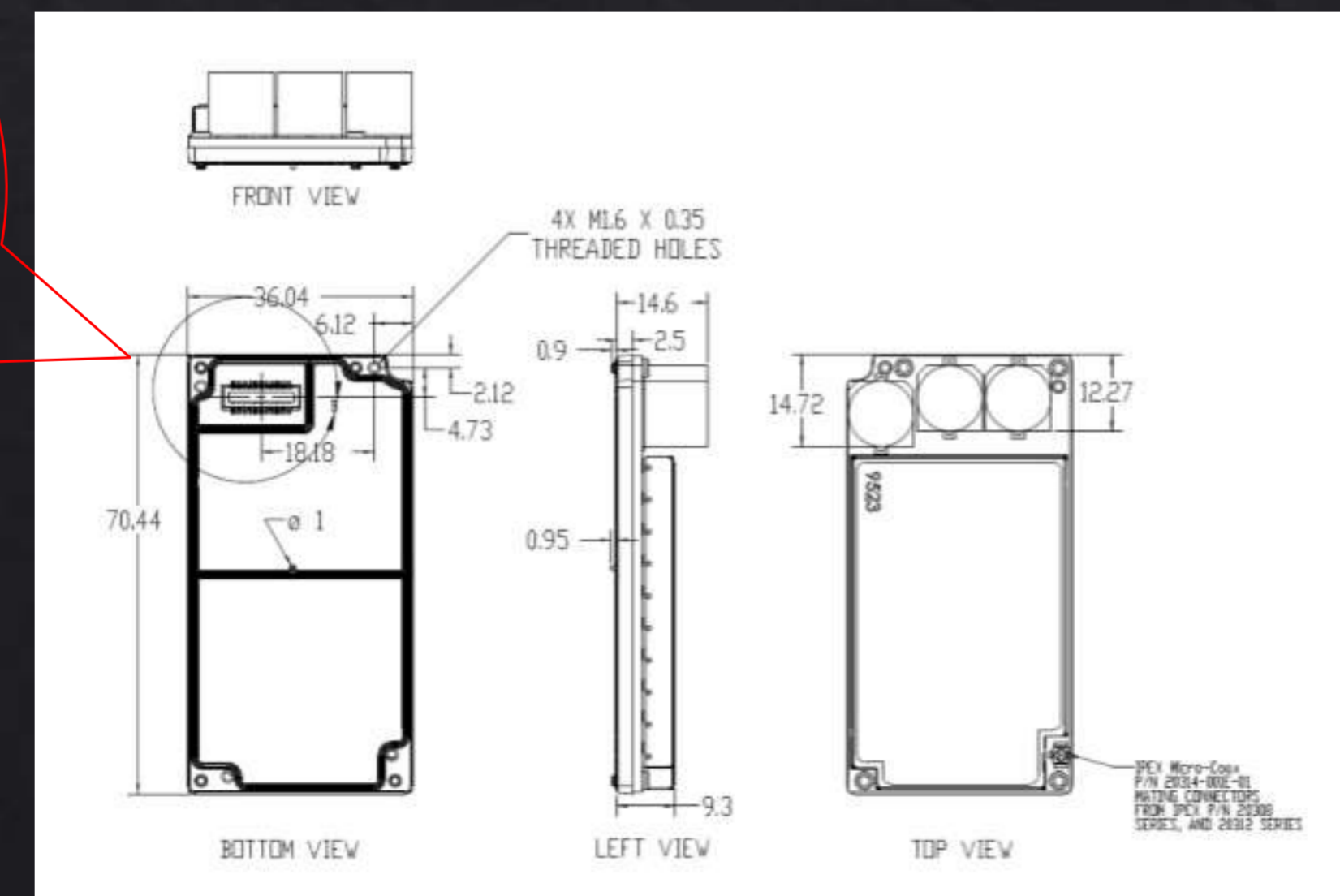
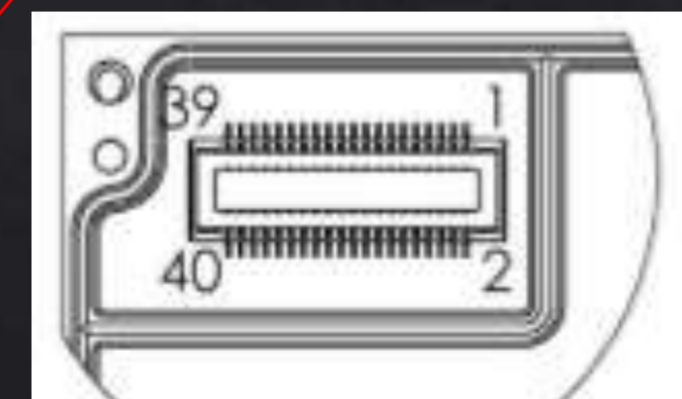
Iridium 9523 consists of a single PCB with components mounted on top and bottom sides.

Top side: three reservoir capacitors, the RF connector, and a screening can covering all remaining circuits.

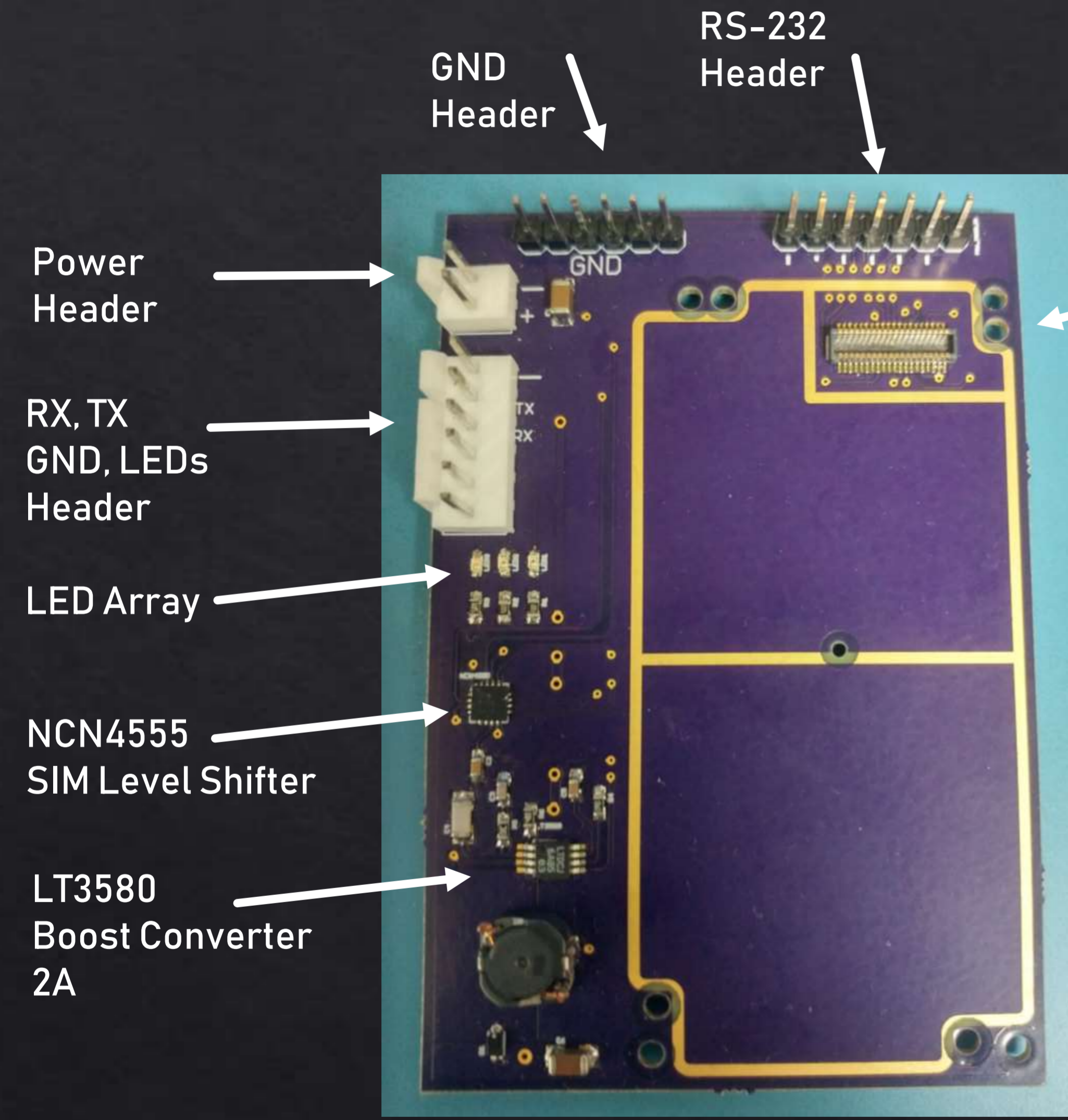
Bottom side: a Molex 40-pin multi-way user interface connector

40-way inter-PCB connector with the following interfaces:

- Digital audio interfaces
- DPL serial asynchronous control port
- Serial asynchronous interface for SIM
- Data/Fax port – serial asynchronous data plus 6 control signals
- GPIO control signals
- Power



Existing PCB Analysis



Iridium 9523 Landing Area



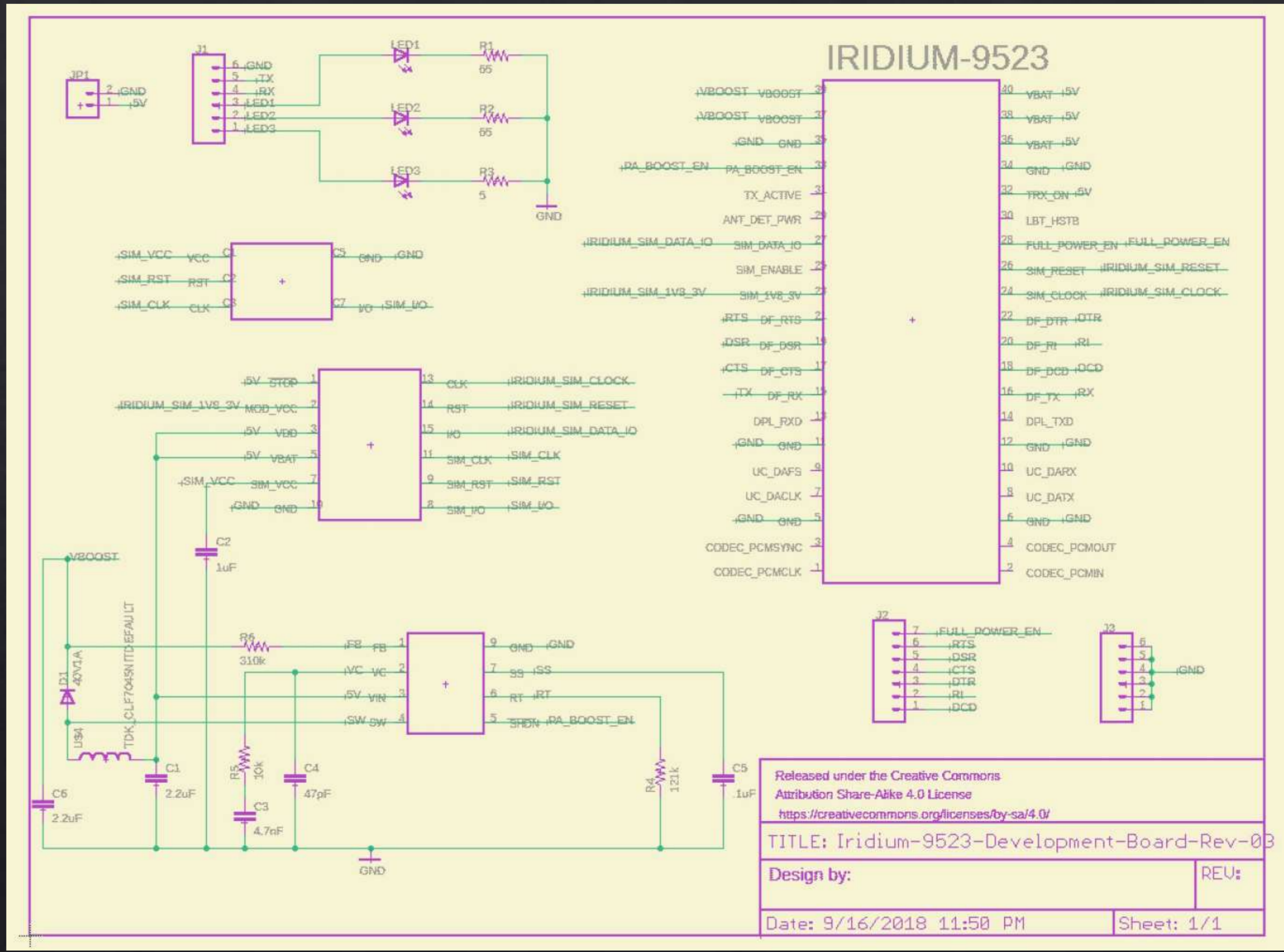
SIM Card Holder

9523 Footprint Test



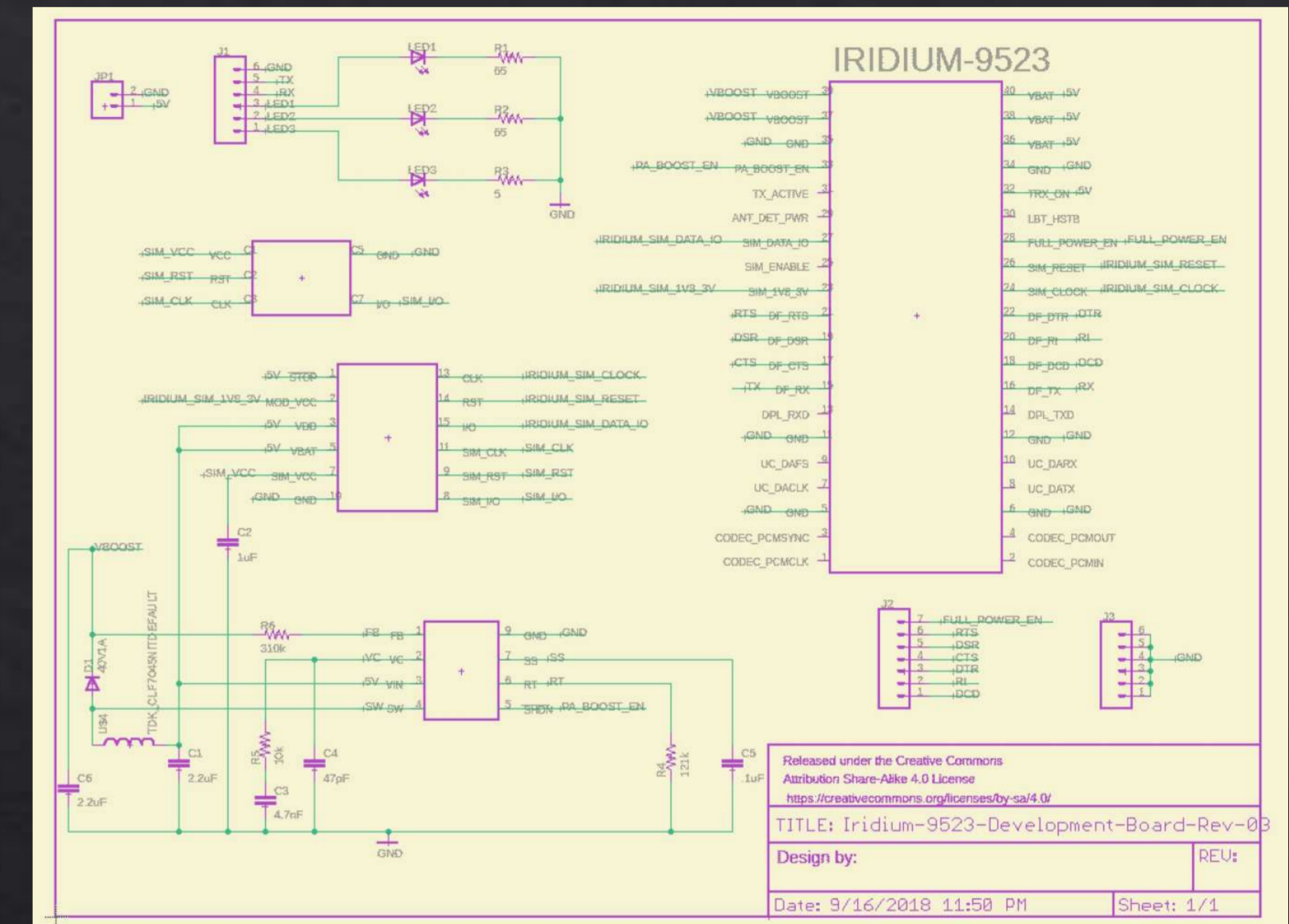
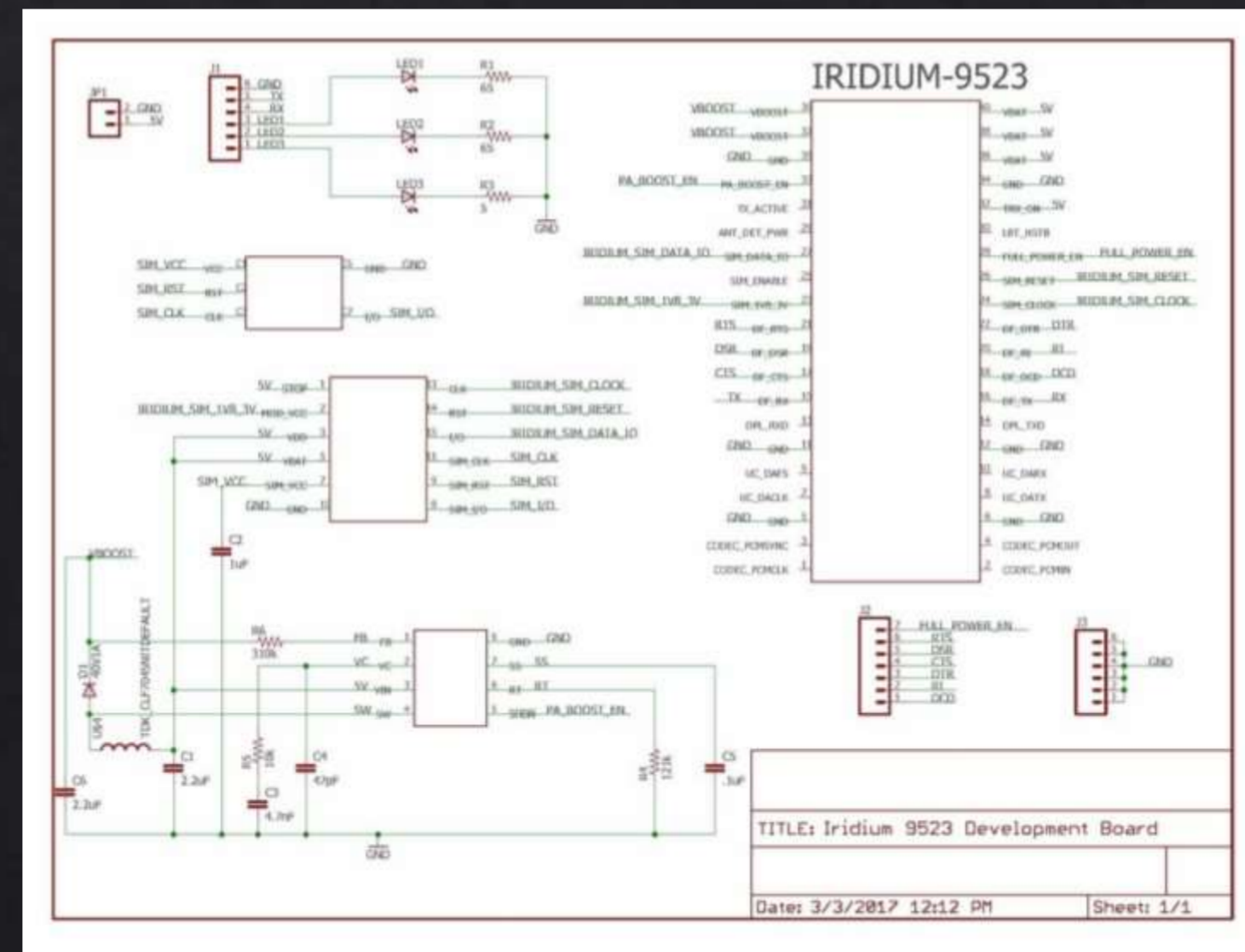
Existing PCB Analysis

- All components are Iridium recommended
- What purpose do LEDs serve?
- Why is there a six-pin ground header?
- Why does the Iridium not function?



Existing PCB Analysis

- PCB is an incomplete copy of the 9523 Development Board
- Pin 30 (mode select) and GPIO float
- Iridium likely never entered modem mode



Team Rocket Schematic

Incomplete Development Board Schematic

Existing Software Analysis

Team ROCKET

- Does not collect data
- Uses short-burst data
- Does not log data
- + Initializes the modem
- Uses CRLF as a command terminator
- Uses a 340/270 byte buffer
- + Has documentation

Team ACOM

- + Collects data
- Uses short-burst data
- + Logs data
- Does not initialize the modem
- + Uses CR as a command terminator
- Does not use a buffer
- Does not have documentation

```
at+sbdwt="test"
Sent: at+sbdwt="test"
at+sbdwt="test"

OK
at+sbd i
Sent: at+sbd i
at+sbd i

+SBDI: 1, 7, 0, 0, 0, 0

OK
at+sbdwt="moscow,id"
Sent: at+sbdwt="moscow,id"
at+sbdwt="moscow,id"

OK
at+sbd i
Sent: at+sbd i
at+sbd i
at+sbd i
Sent: at+sbd i
at
+SBDI: 1, 8, 0, 0, 0, 0

OK
+48088160334001430530
```

ACOM SBD Test

NAL A3LA-RS Analysis

- Iridium 9523 'black box' known to work
- Standard RS-232 DB-15 via ST3237
- Obviously taken apart several times

Same main components:

- NCN4555
- LT3580

Missing four M1.6-.35 screws holding 9523 to PCB



Iridium Module Development

Iridium 9523 Module Requirements

- IR-1.1: The Iridium 9523 module shall be able to integrate with the current TES electronics stack
- IR-1.2: The Iridium 9523 module shall act as an internet modem to stream data from TES subsystems
- IR-1.3: The Iridium 9523 module shall be able to establish a reliable link to a ground-based server
- IR-1.4: A ground-based server shall securely store all data received from the Iridium 9523 module for later review and retrieval

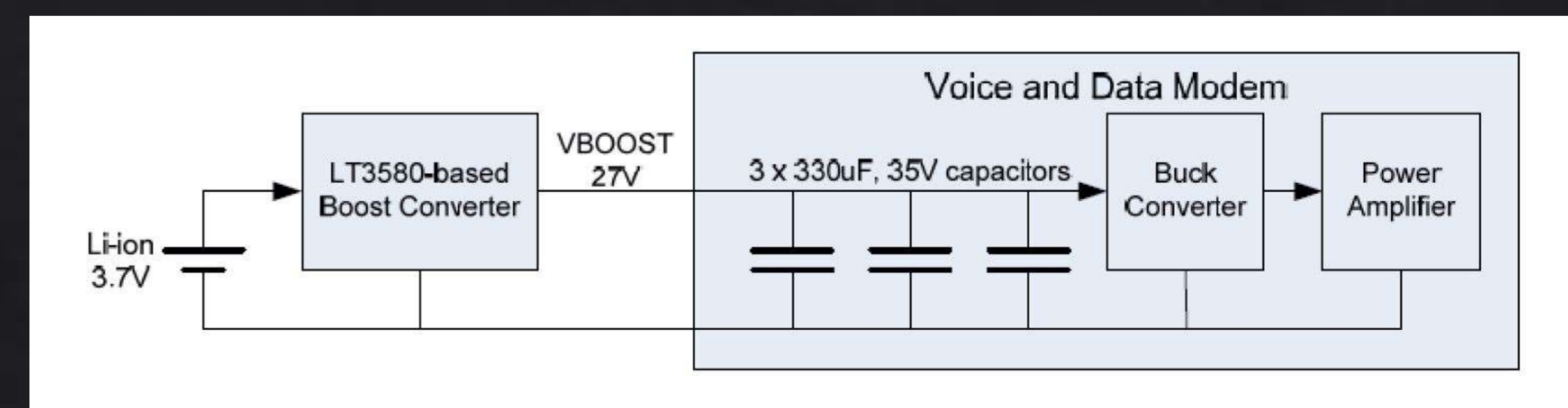
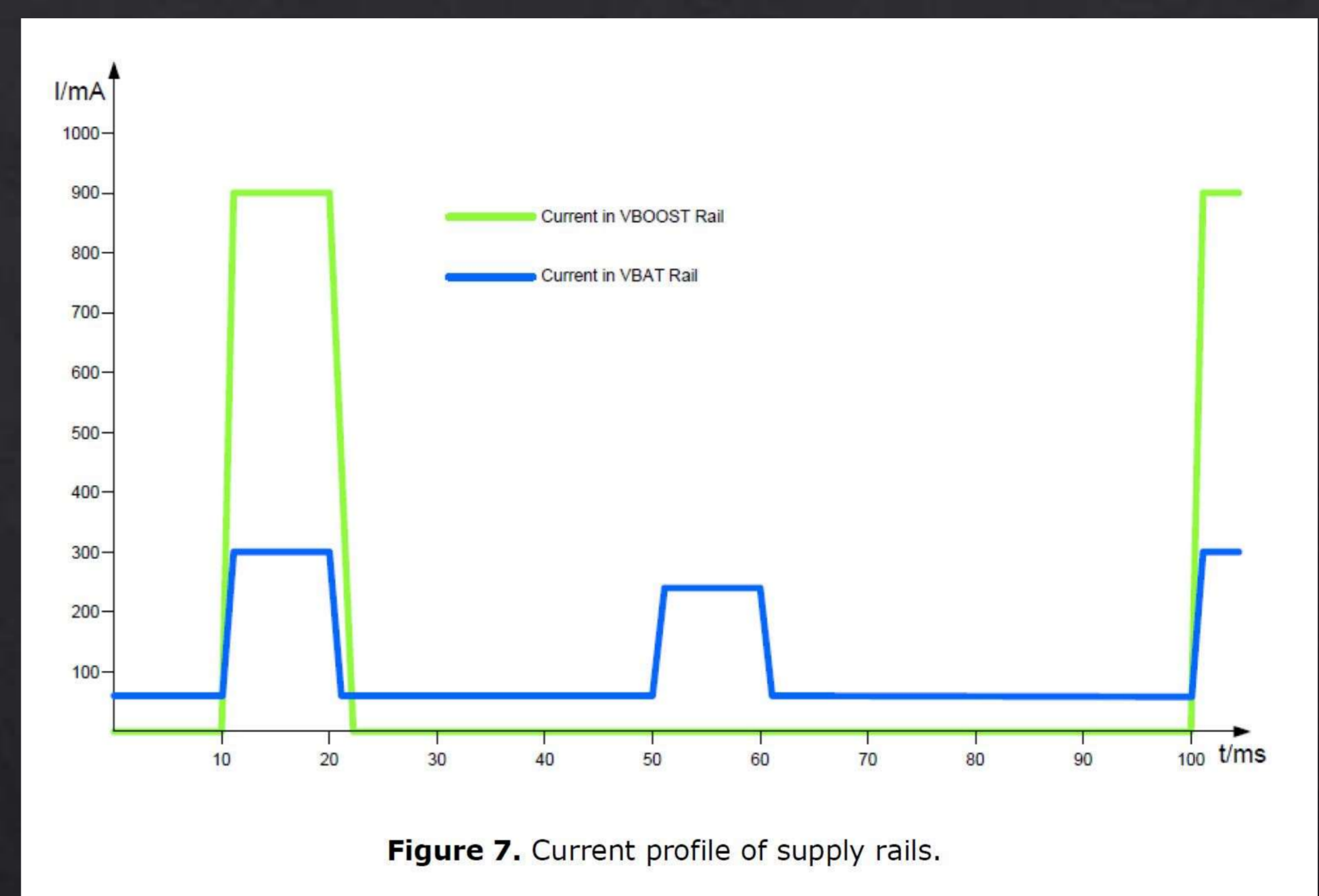
Iridium Power Requirements

Dual voltage supply:
 VBAT: 3.2-6VDC, 500mA
 VBOOST: 27-32VDC, 1A

VBOOST supplies RF transmit
 circuitry
 8.3ms pulse every 90ms

Relies on charging ~1000uF of
 Aluminum electrolytic capacitors
 to supply internal buck converter

Capacitors will likely fail in
 expected -30-60°C hard vacuum



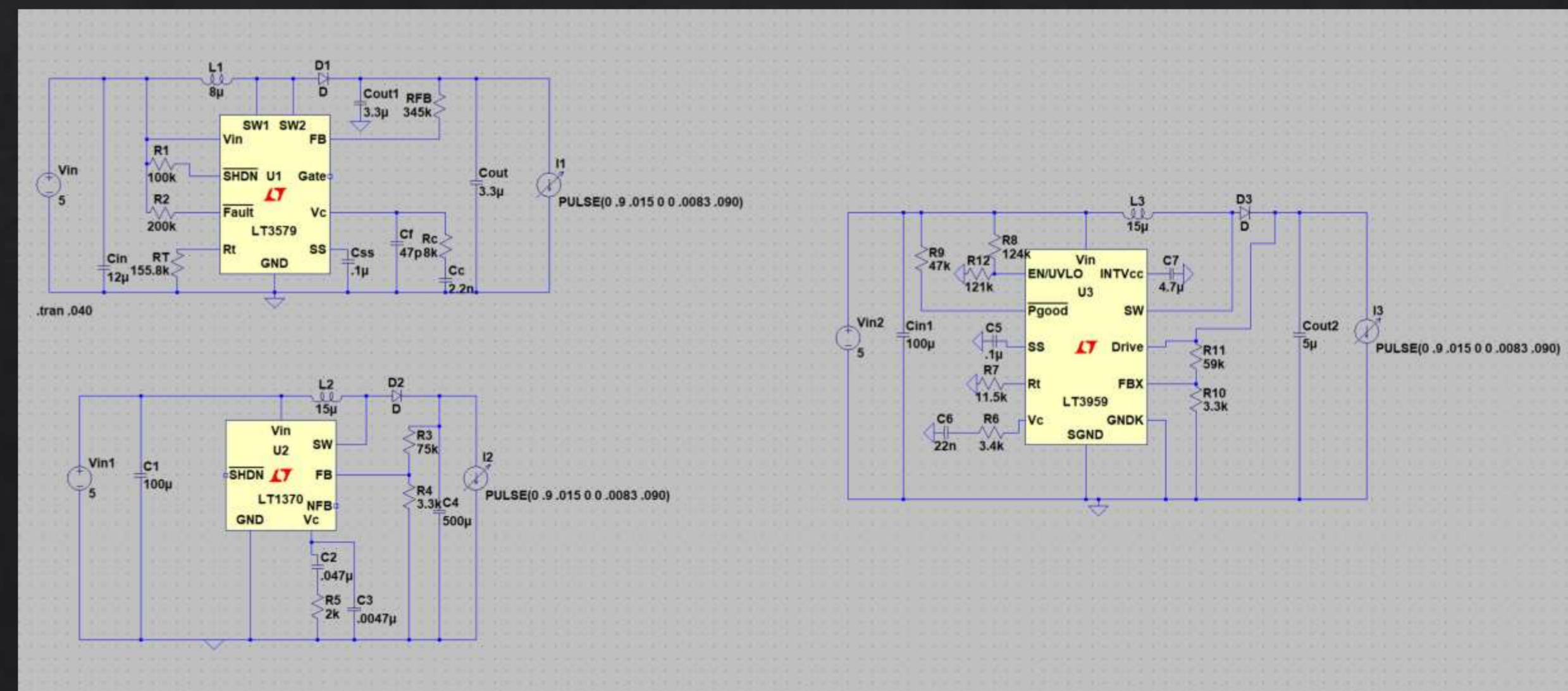
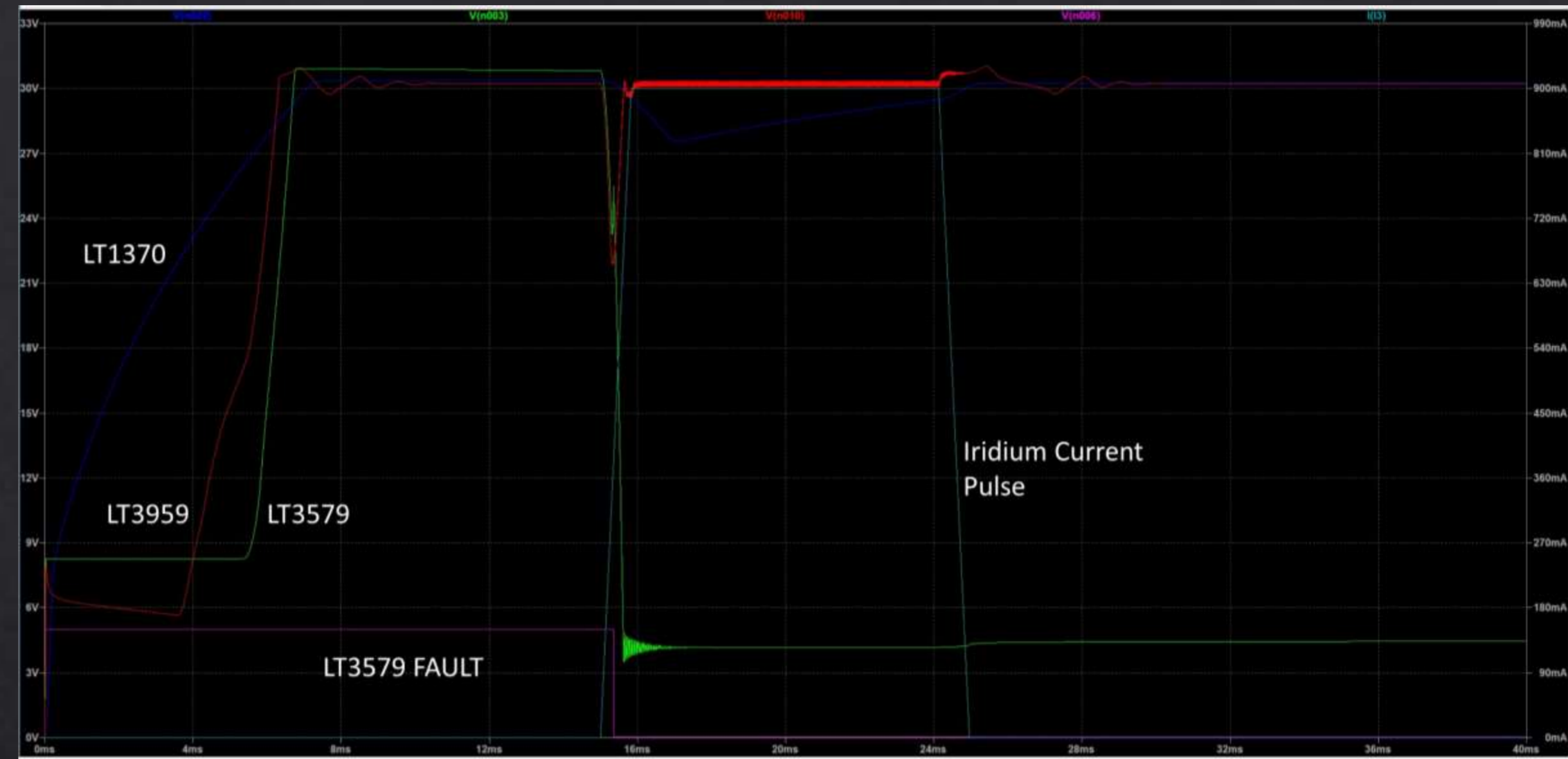
Boost Regulator Selection



Requirements:
Boost 5VDC to 30VDC 1A

Initial choices:

Part	Cost	Max Current	Max Vout	Freq Range	PKG	Temp range	CAD Model Available?	Notes
LT1268	\$12.69	7.5A	60V	150KHz	5-DDPAK	0-125°C	Yes	-No EN Pin -Simple Circuit -Bare-Bones
LT1370	\$14.86	7A	35V	500KHz	D2PAK-7	-40-125°C Variant	Yes	-EN Pin -Simple Circuit -Bare-Bones
LT3957	\$7.38	6A	40V	100KHz-1MHz	36-QFN	-40-125°C	Yes	-Programmable Frequency -EN Pin -Simple Circuit
LT3959	\$7.66	7A	40V	100KHz-1MHz	36-QFN or 38-TSSOP-EP	-40-125°C	Yes	-EN pin -PWR status pin -Simple Circuit
LT3579	\$7.50	7.5A with FETs in parallel	42V	200KHz -2.5MHz	20-QFN or 20-TSSOP-EP	-40-125°C	Yes	-Fault protection -Programmable frequency -EN pin -Temperature Output -Fault warning -Simple Circuit - 42V master/slave switches



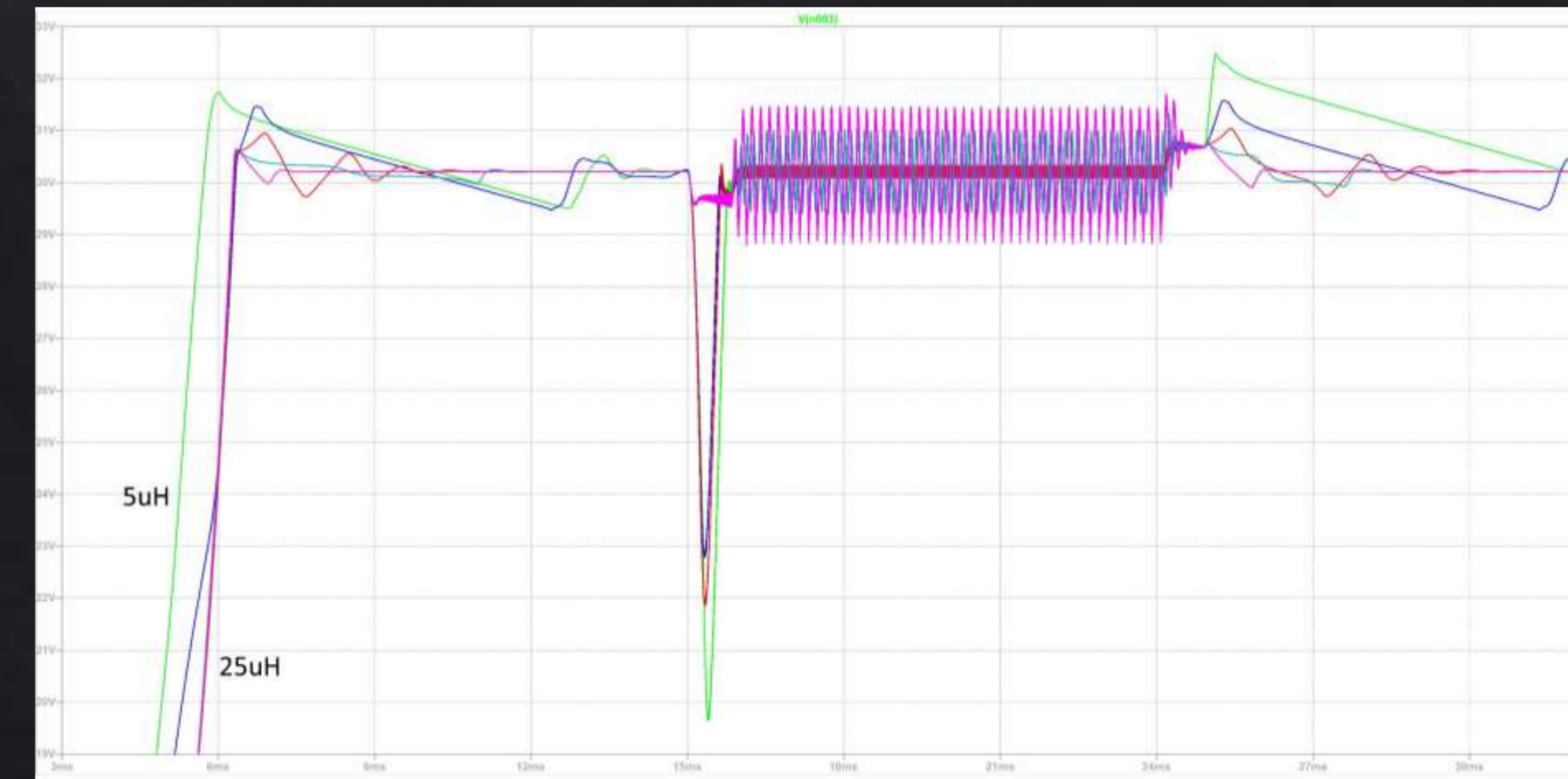
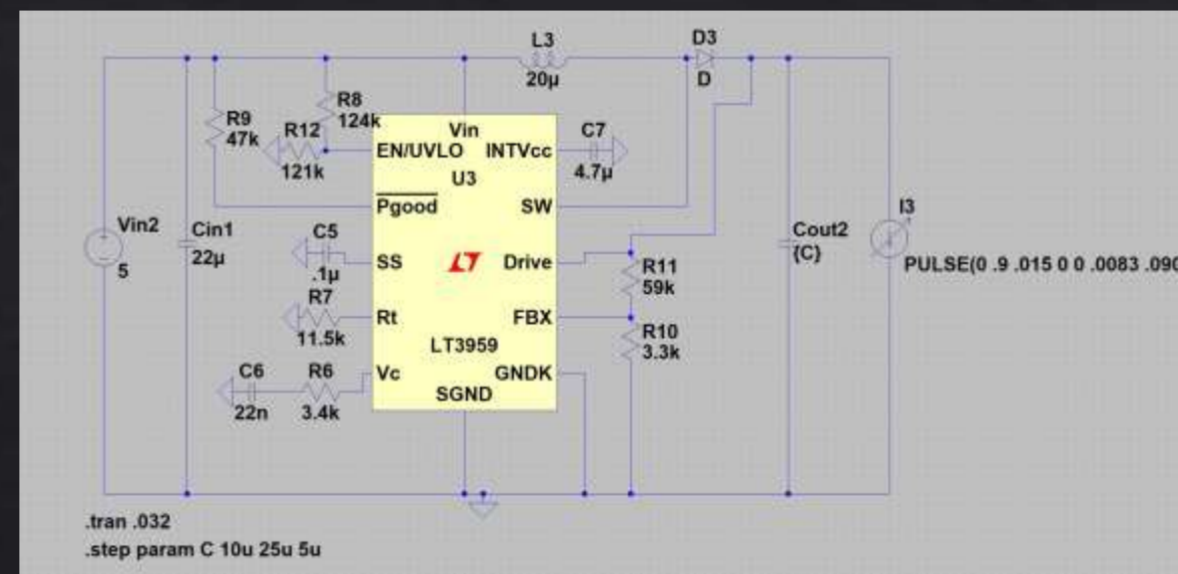
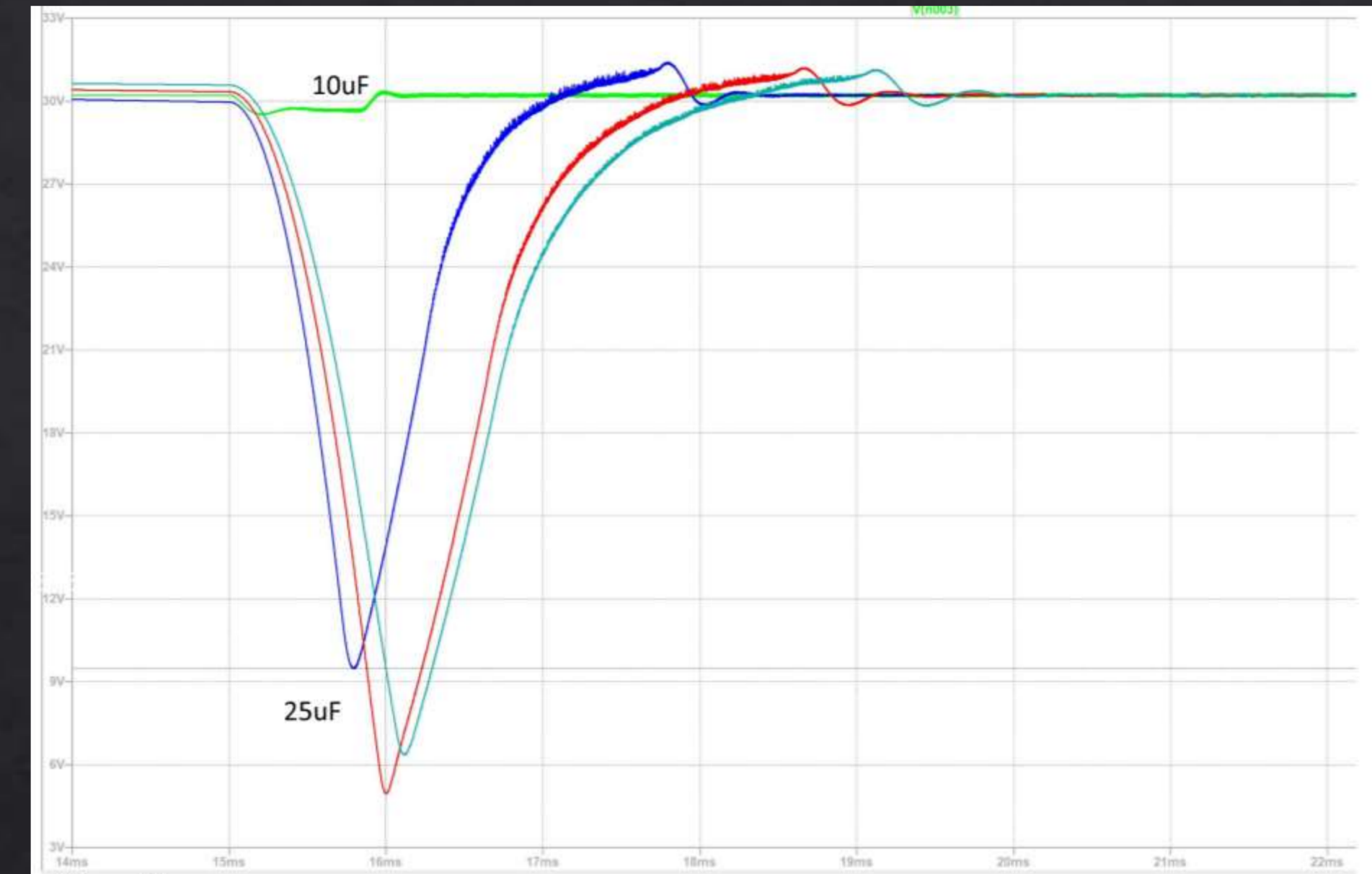
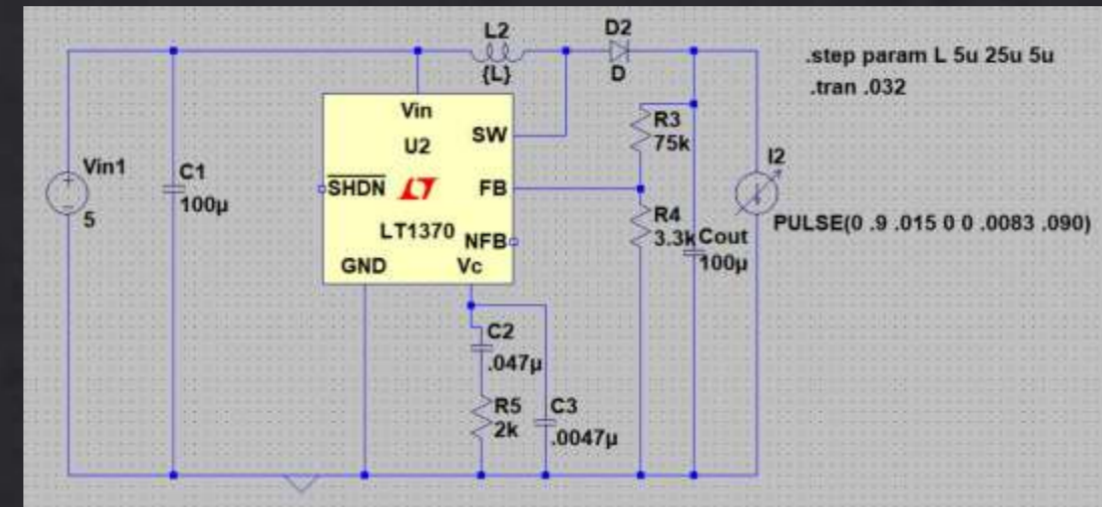
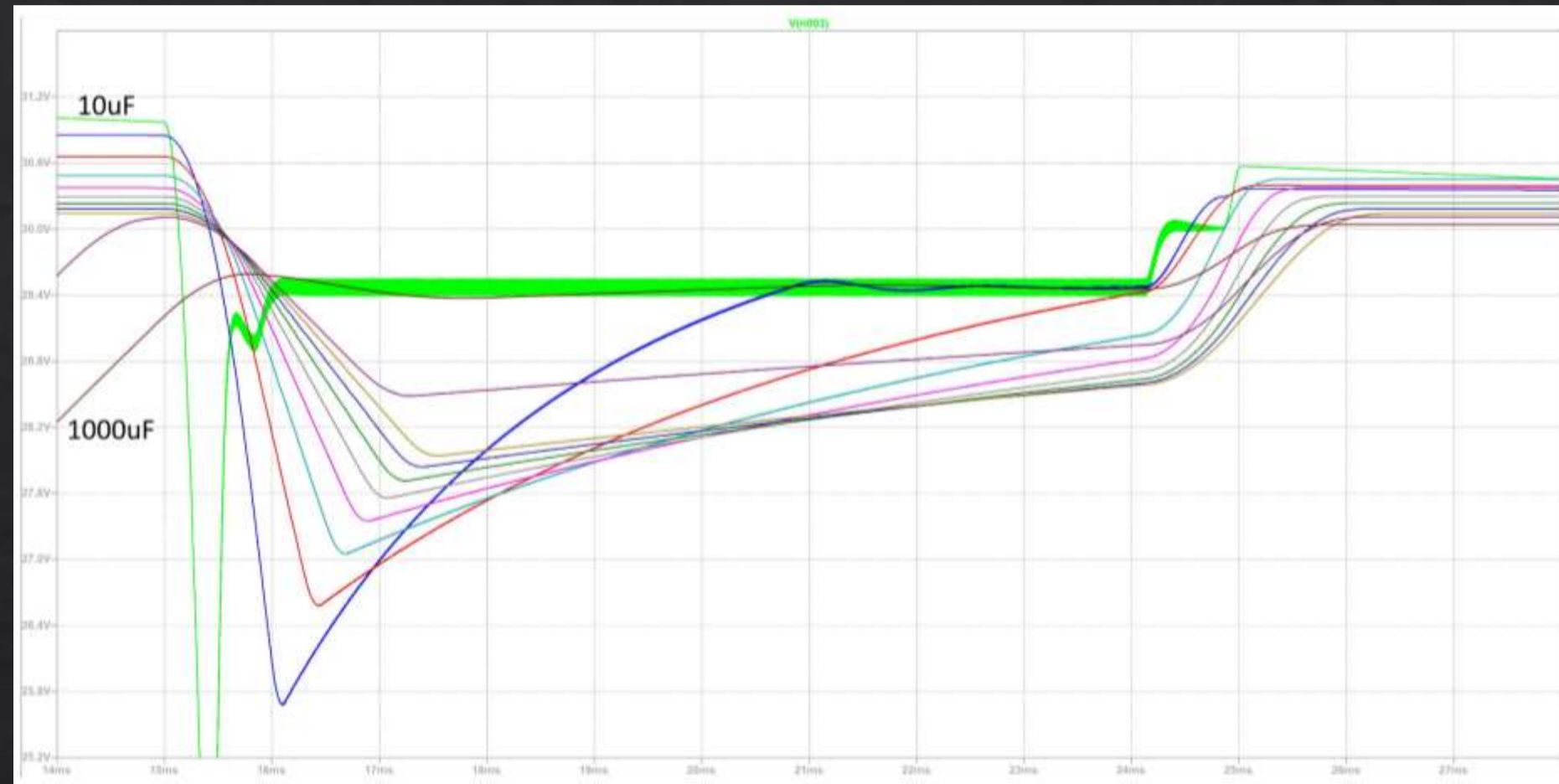
LT1268, LT3957 disqualified
LT3579, 1370, 3959 simulated
LT3579 Fails

Boost Regulator Optimization



LT1370

LT3959



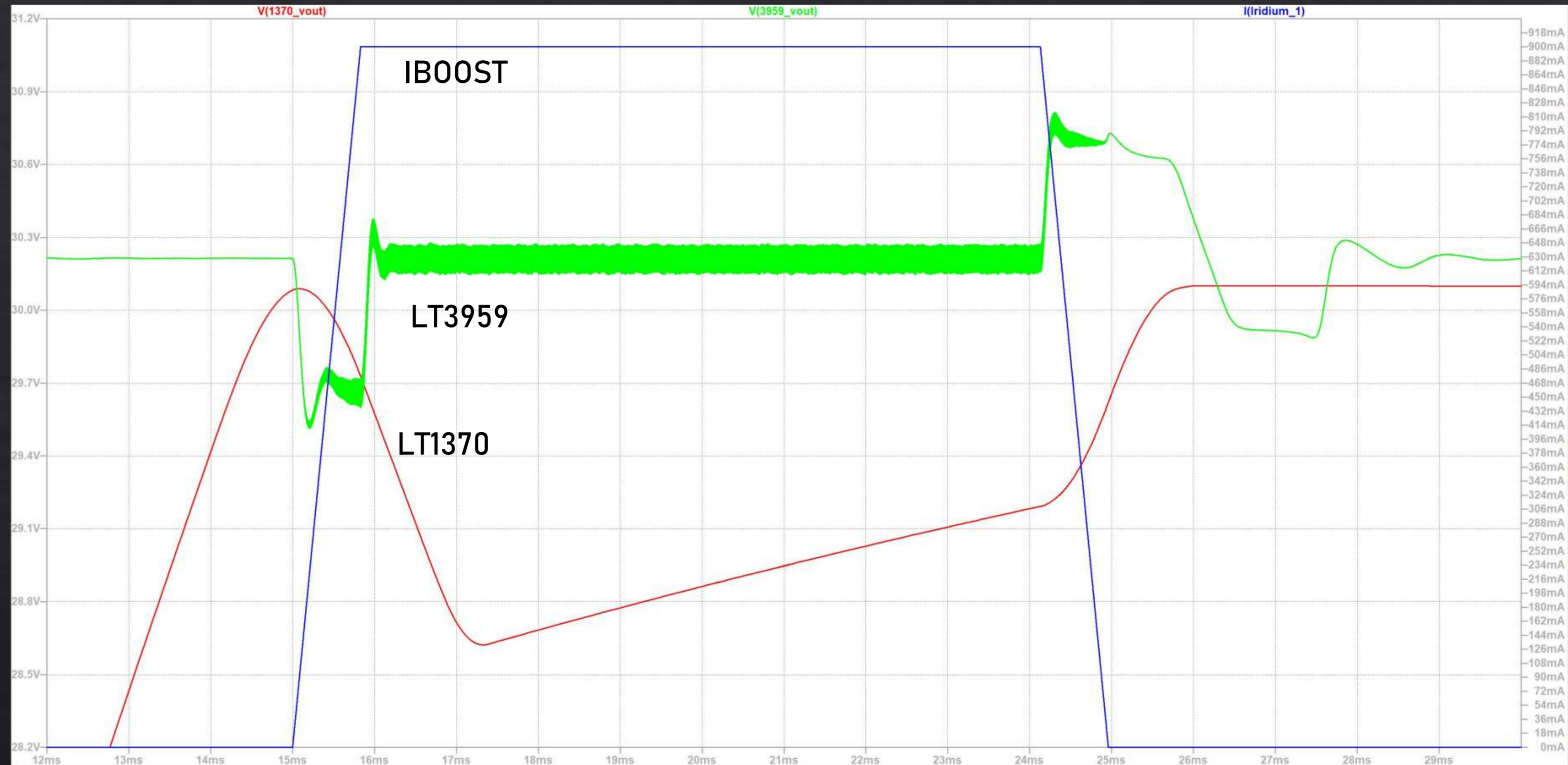
Results



LT1370:
6uH-8uH Inductor
900uF minimum
capacitance

LT3959
20uH-25uH Inductor
6uF-13uF capacitance

3959 has overall better
performance



LT3959 Verification

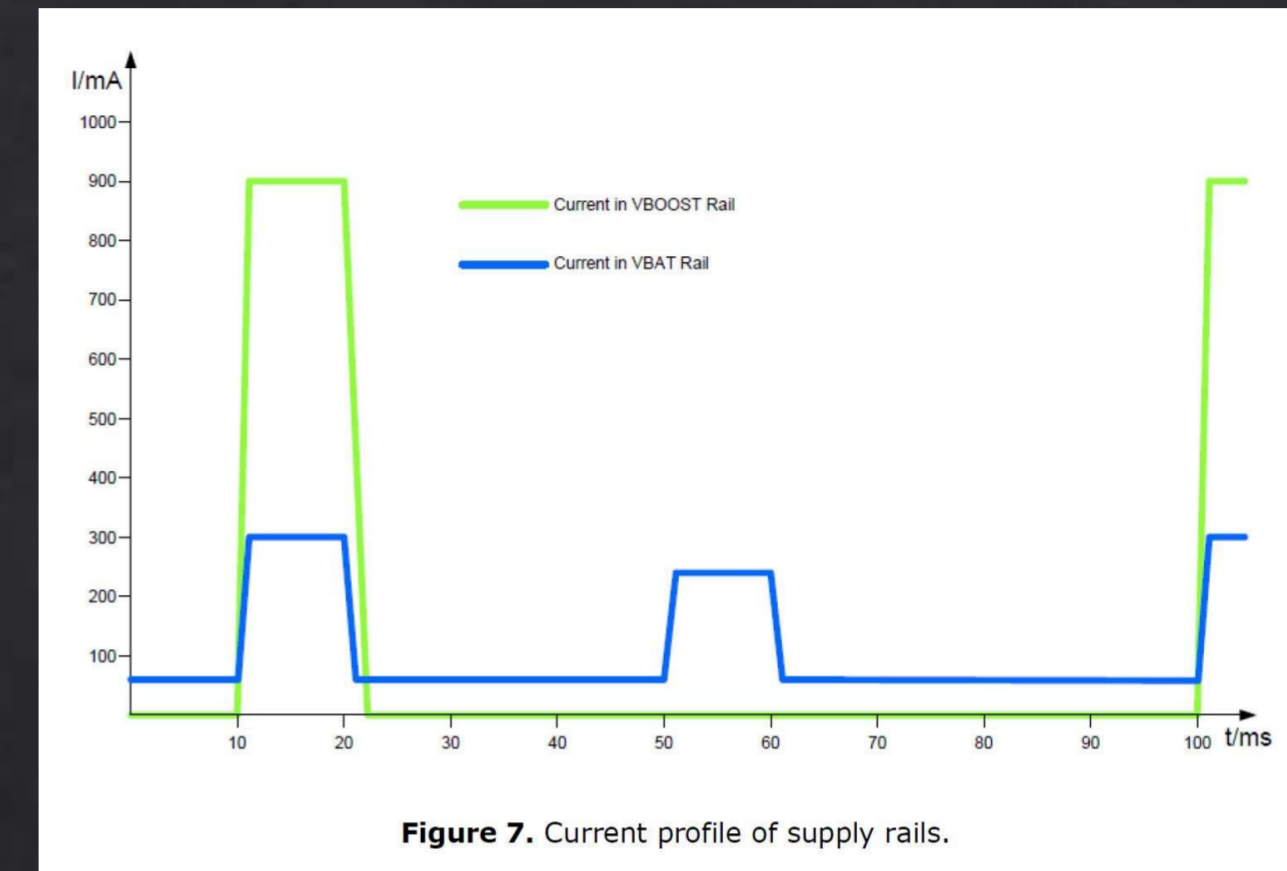
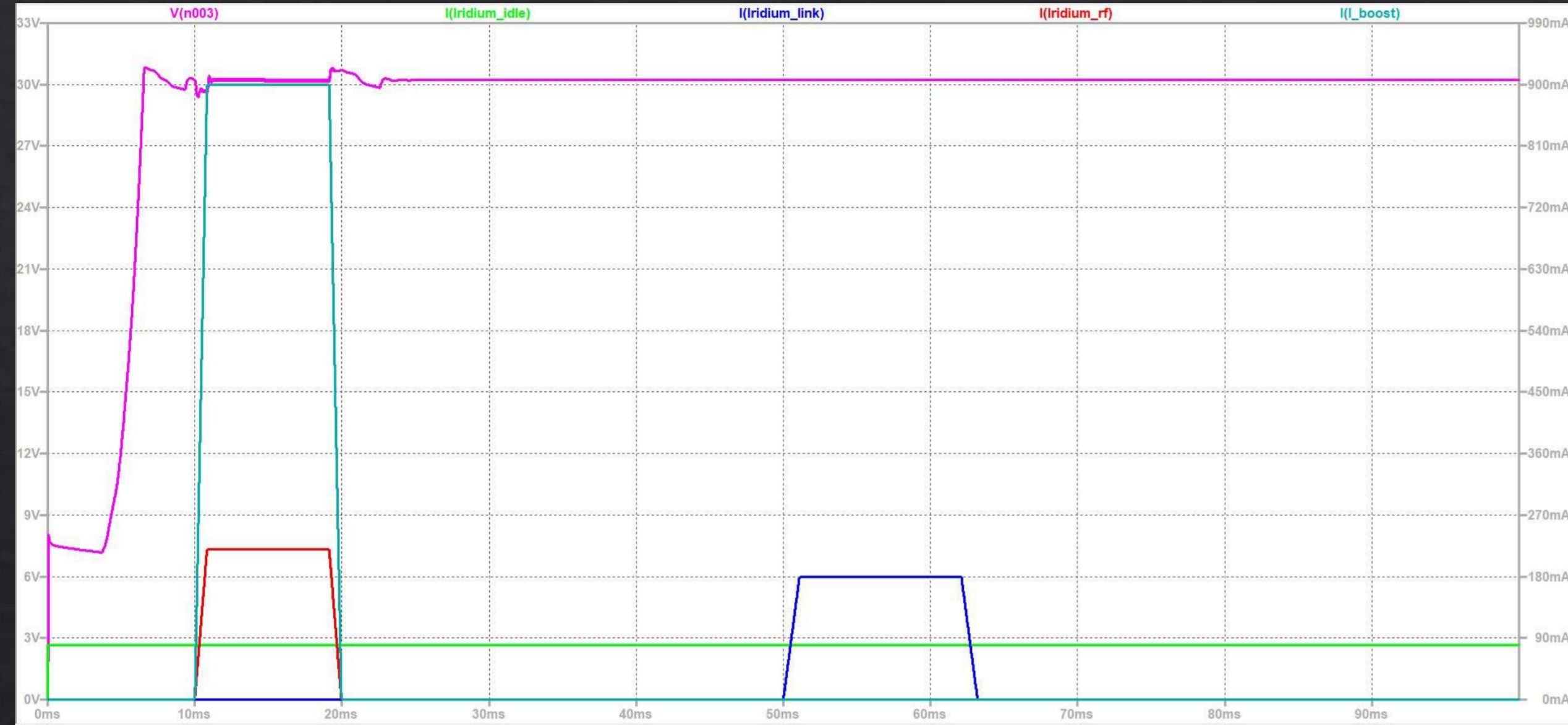
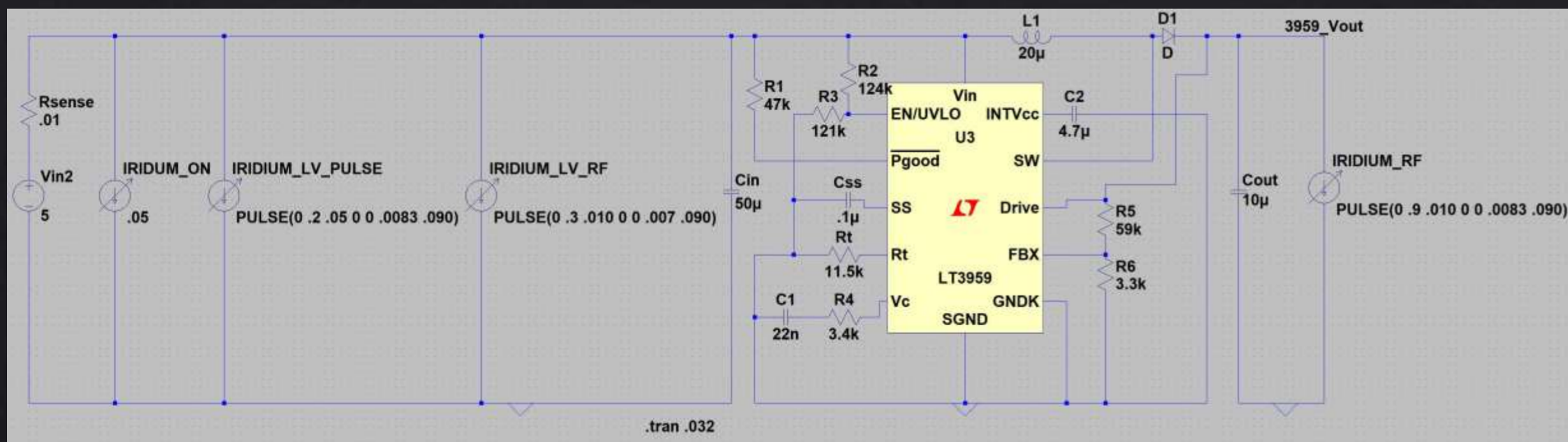


Figure 7. Current profile of supply rails.



Iridium 9523 Requirements

Must Tri-state port pins to prevent latch-up

Must not enable board without first applying power

Must disable local GPS devices to prevent damage

Minimum 20cm safe distance from antenna at full power

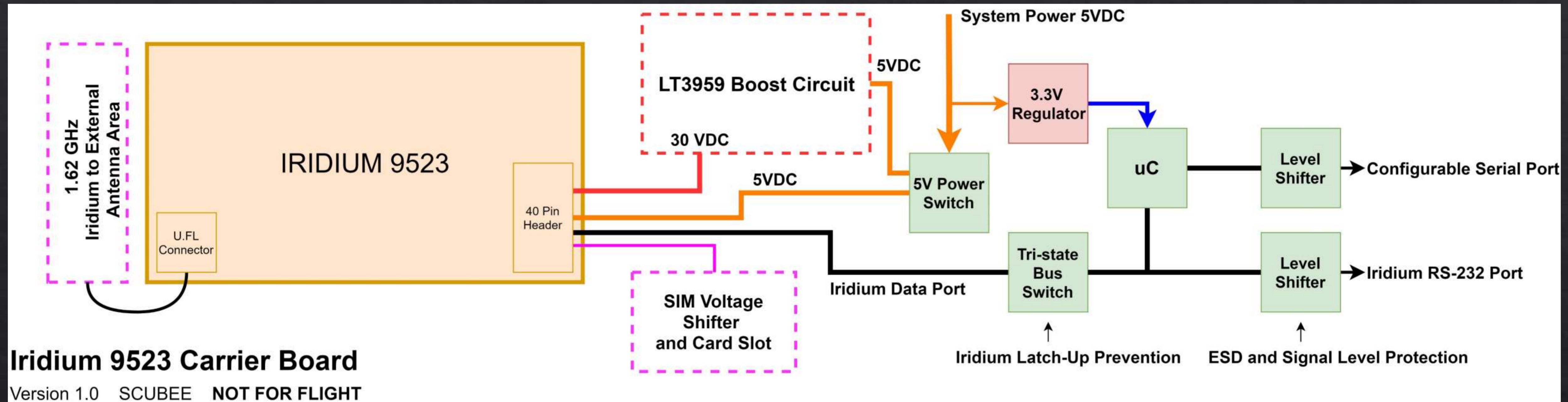
Minimum 2s delay between shutdown/boot



Analog area
Must have
solid ground
plane

Power area
Ideally solid
ground plane

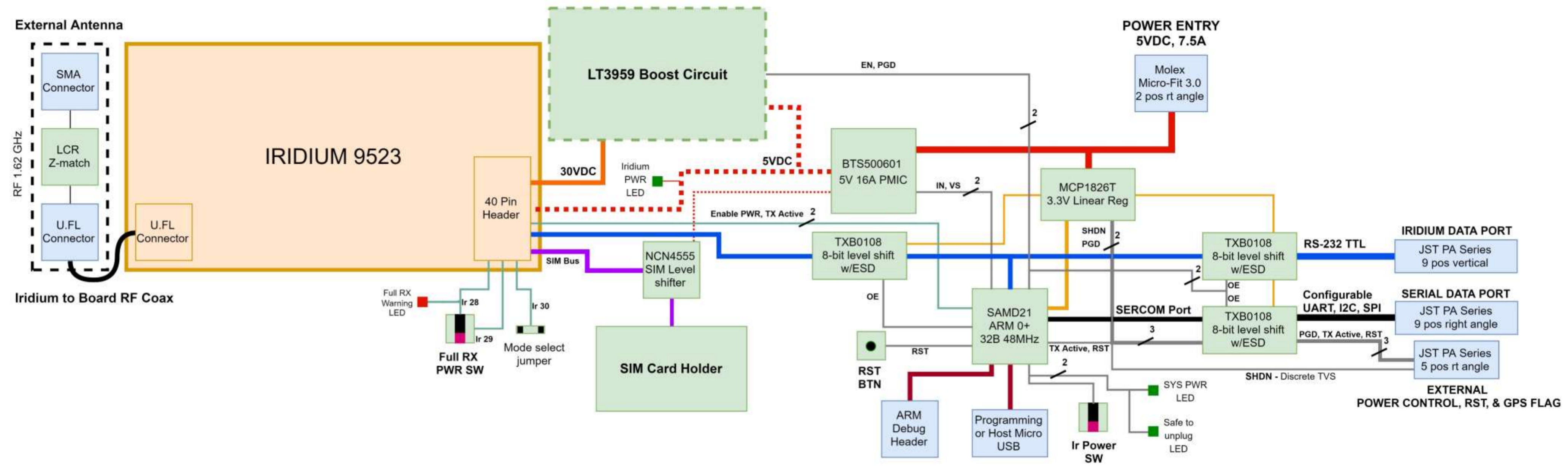
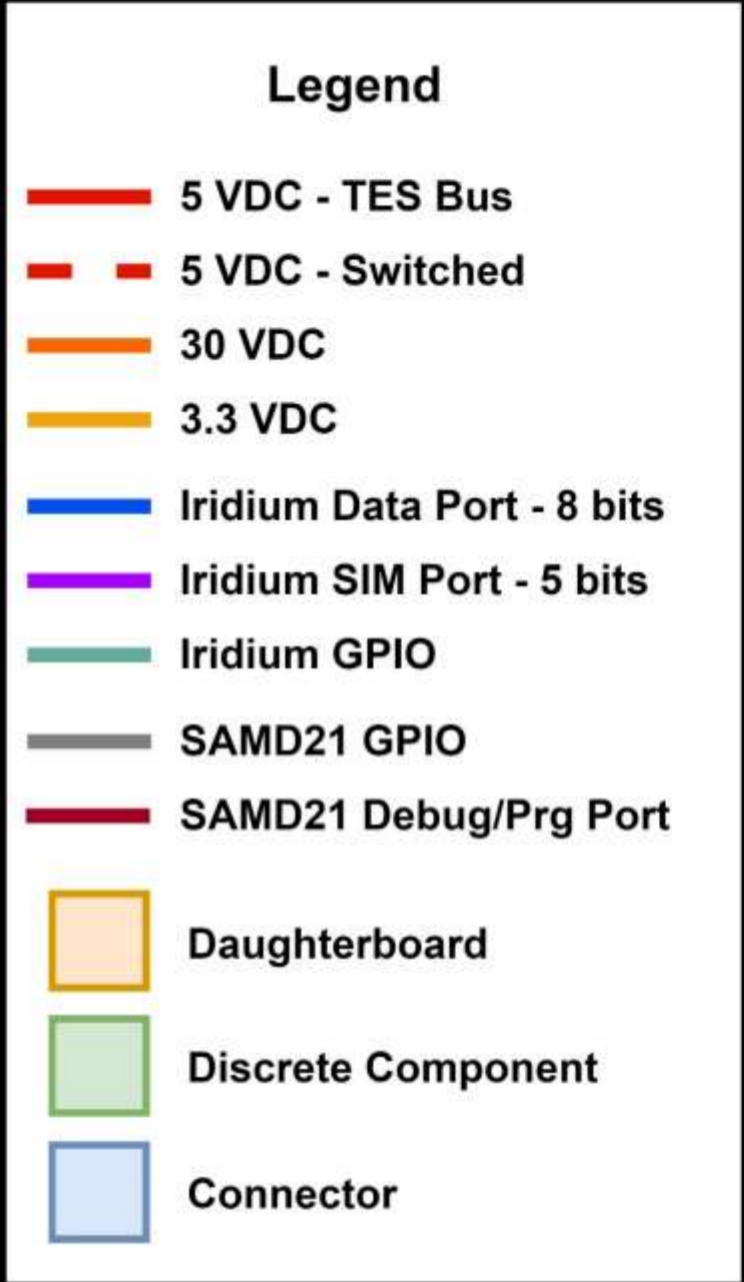
Iridium Carrier Diagram



Microcontroller provides configurable communication interface and performs modem setup, translation, and shut down tasks

Initial testing shall be conducted using a Raspberry Pi connected to the Iridium RS-232 port, then code will be ported to the uC

Iridium Carrier Diagram

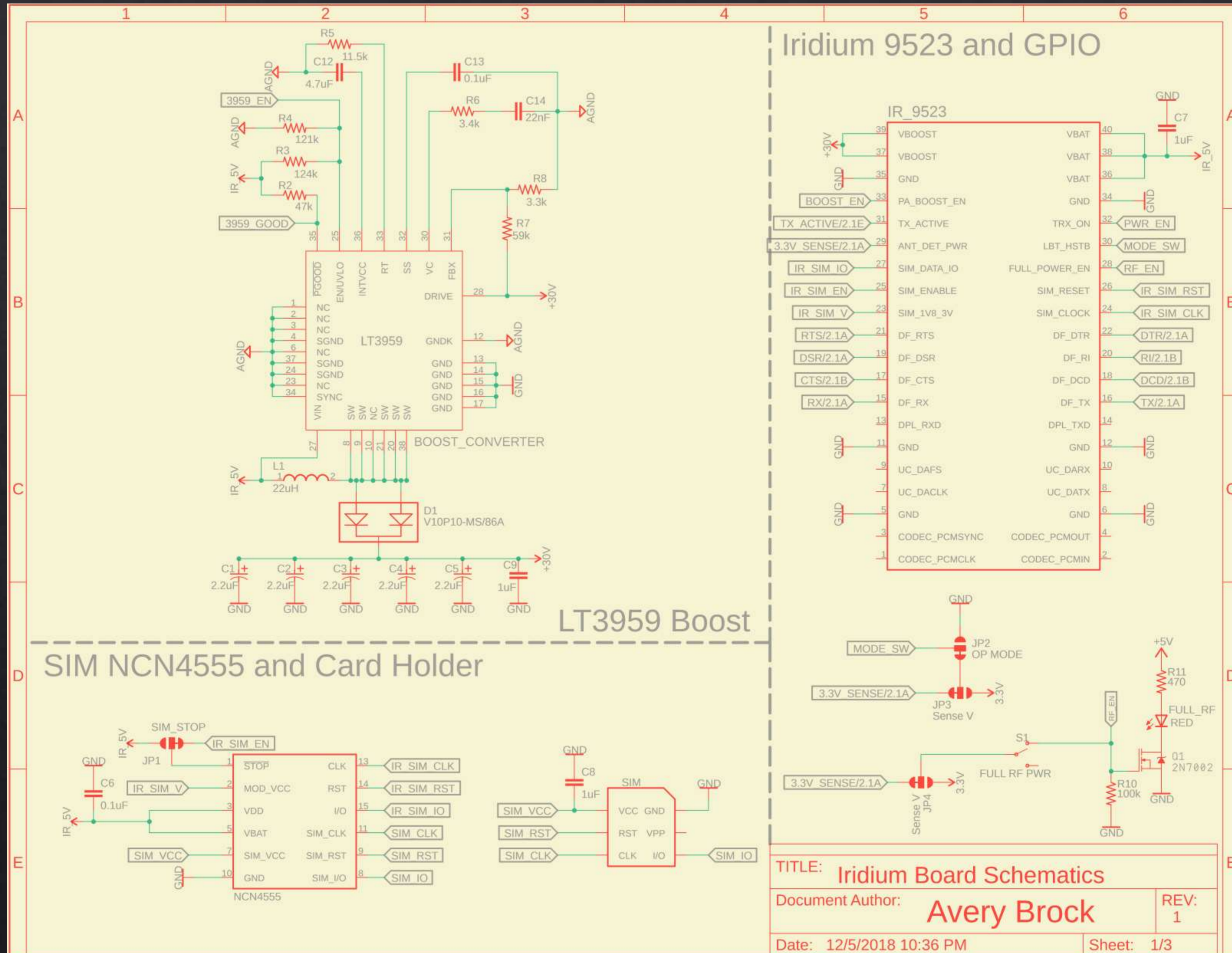


Iridium 9523 Carrier Board Details
Version 1.0 SCUBEE NOT FOR FLIGHT

Flight Modifications:

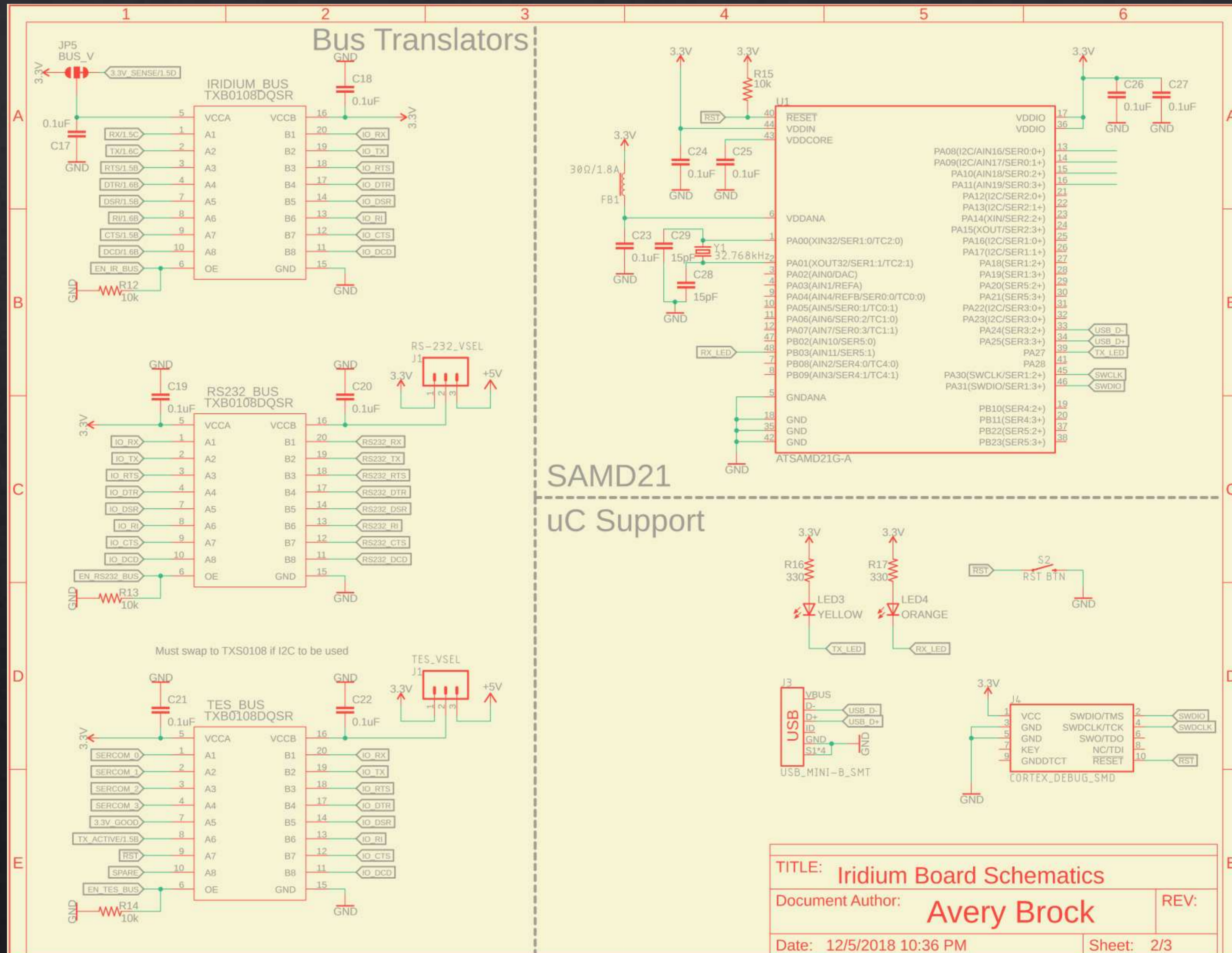
- Direct Iridium port connection and associated components, LEDs, and configuration switches/jumpers to be removed
- Data and External control ports shall be combined to a single 9-pin connector

Iridium Carrier Schematic



TITLE: Iridium Board Schematics
 Document Author: Avery Brock
 Date: 12/5/2018 10:36 PM
 REV: 1
 Sheet: 1/3

Iridium Carrier Schematic



TITLE: Iridium Board Schematics	
Document Author: Avery Brock	REV:
Date: 12/5/2018 10:36 PM	Sheet: 2/3

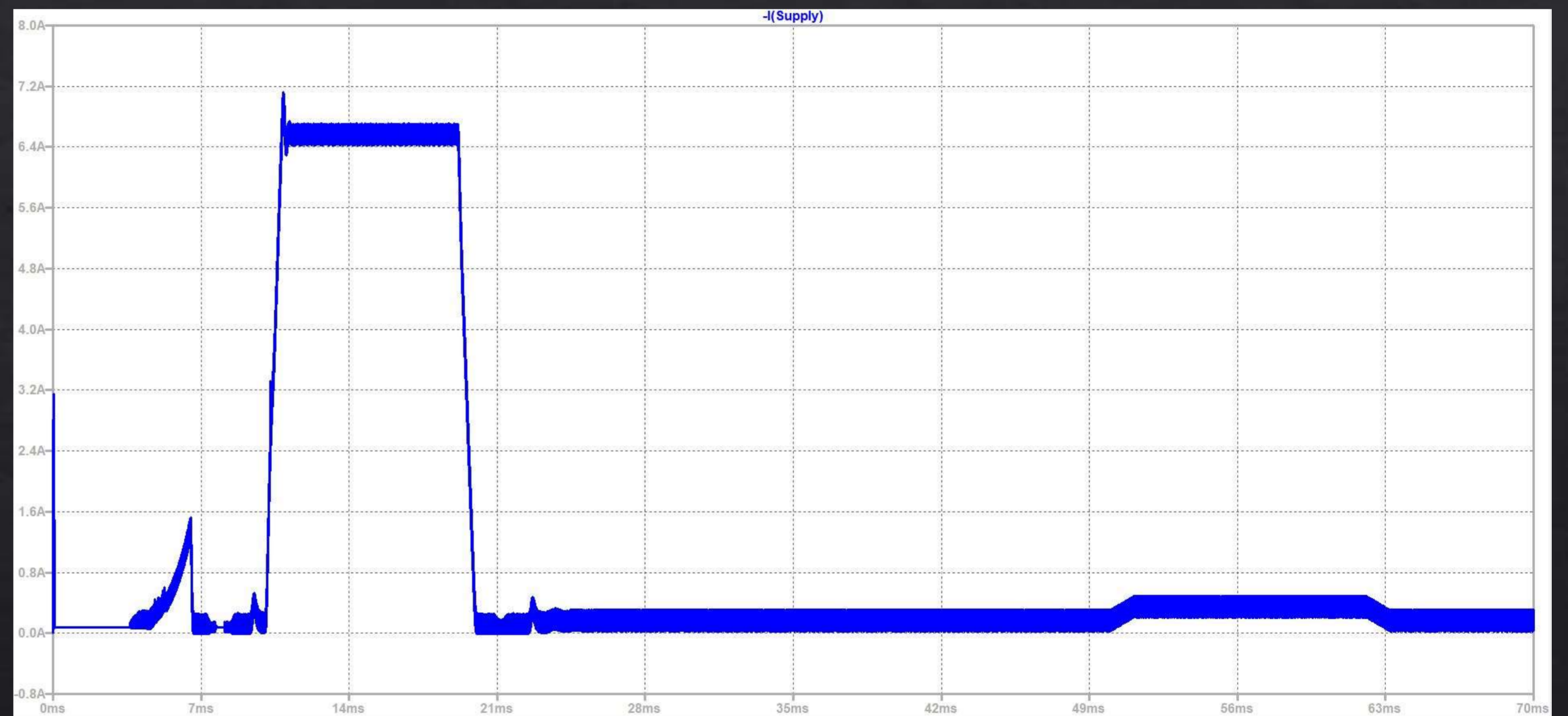
Power and Communication

Power Supply:

- 5 VDC
- 7A Peak Consumption
- Dual voltage feed would reduce current consumption

Communication:

- 3.3/5V TTL RS-232 9-wire
- 3.3/5V SPI, I2C, Serial
- TTL signals for additional control
- Special considerations needed if I2C/SMBus desired



Iridium Antenna

The Iridium 9523 should be connected to a certified Iridium-band antenna with the following antenna connector characteristics:

General RF Parameters

PARAMETER	VALUE
VSWR	1.5 : 1
Maximum Gain	3 dBic
Nominal Impedance	50 Ohms
Polarization	Right Hand Circular (RHCP)

Antenna Characteristics

PARAMETER	VALUE
Frequency Range	1616 MHz to 1626.5 MHz
Duplexing Method	TDD (Time Domain Duplex)
Input/Output Impedance	50 Ohms
Multiplexing Method	TDMA/FDMA



	IAA.01.12111	M1621HCT-EXT	M1621HCT-P-UFL
Price(\$)	25.86	56.97	Waiting for quotation
Size(mm)	40.5*38*12.3	52.2*36	33*13.2
Frequency(MHz)	1616-1626.5	1616-1626	1616-1626
Peak Gain(dBic)	lacking	1	2.8
Efficiency	lacking	50%	60%
Weight(grams)	lacking	52	30

TDRV Development

Previous Testing

Background:

- Previous testing of TDRV designs consisted of a singular drop test
- Experiments such as dropping the TDRV from the University of Idaho Kibbie Dome not only tested the capability of electrical components surviving impact, but validated the use of descent arrestors in drag force braking

Results:

- Results showed promising criteria for slowing the TDRV, but lacked adequate stabilization upon descent. Future TDRV arrestors will be modified to further stabilize the return trip.

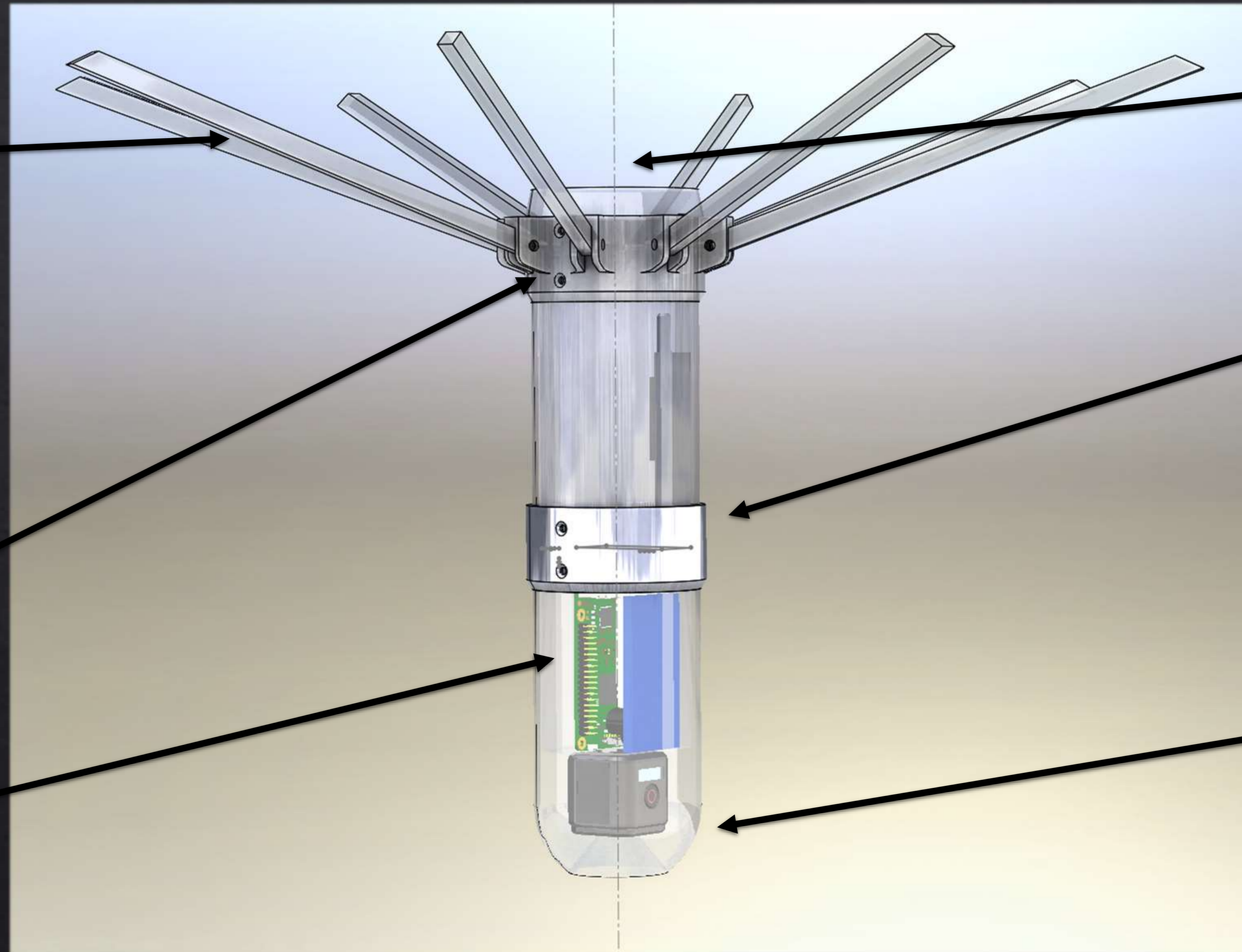


Planned TDRV Improvements

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 rail-mounted end cap with threaded end cap

Reconstruct interior to accept configurable electronics tray



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

Planned TDRV Improvements

- **Nose Cap**
 - Nose will be separated from body to allow for access to GoPro camera.
 - Cap will be threaded on outer edge for secure fitting to primary TDRV body.

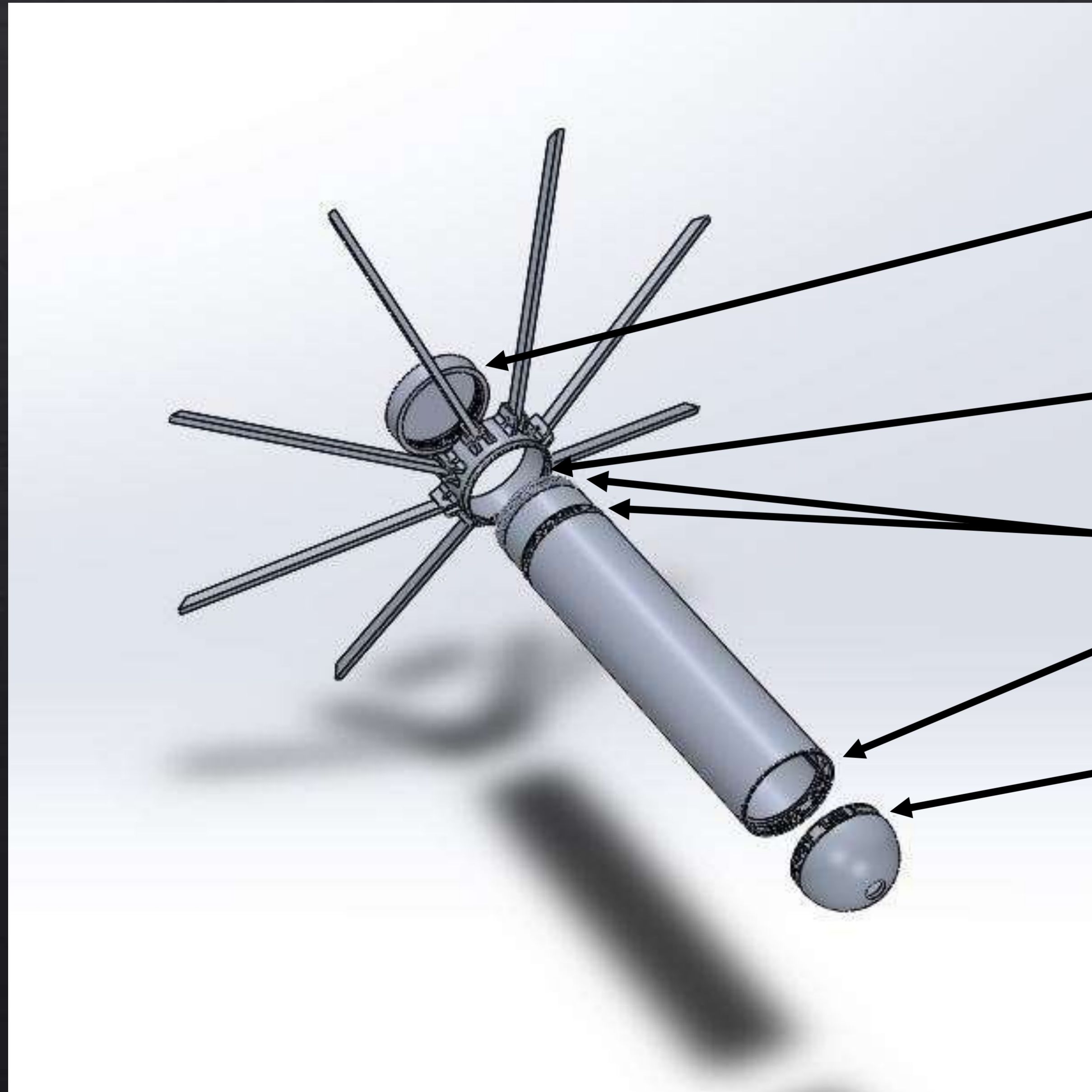
- **Descent Arrestors**
 - Current arrestors provide too much drag with little stability.
 - Arrestors will be shortened for smaller drag surface area.
 - Angle of attack will be increased by allowing further arrestor deployment before hard stop is initiated on connecting bracket.



Questions:

- Preferred material for TDRV shell construction?
- Finalized accepted dimensions of TDRV?

Current TDRV CAD



Threaded female end cap without modification for antennae

Threaded female end strut ring

Threaded male end main body

Threaded female end main body

Threaded male end nose cap

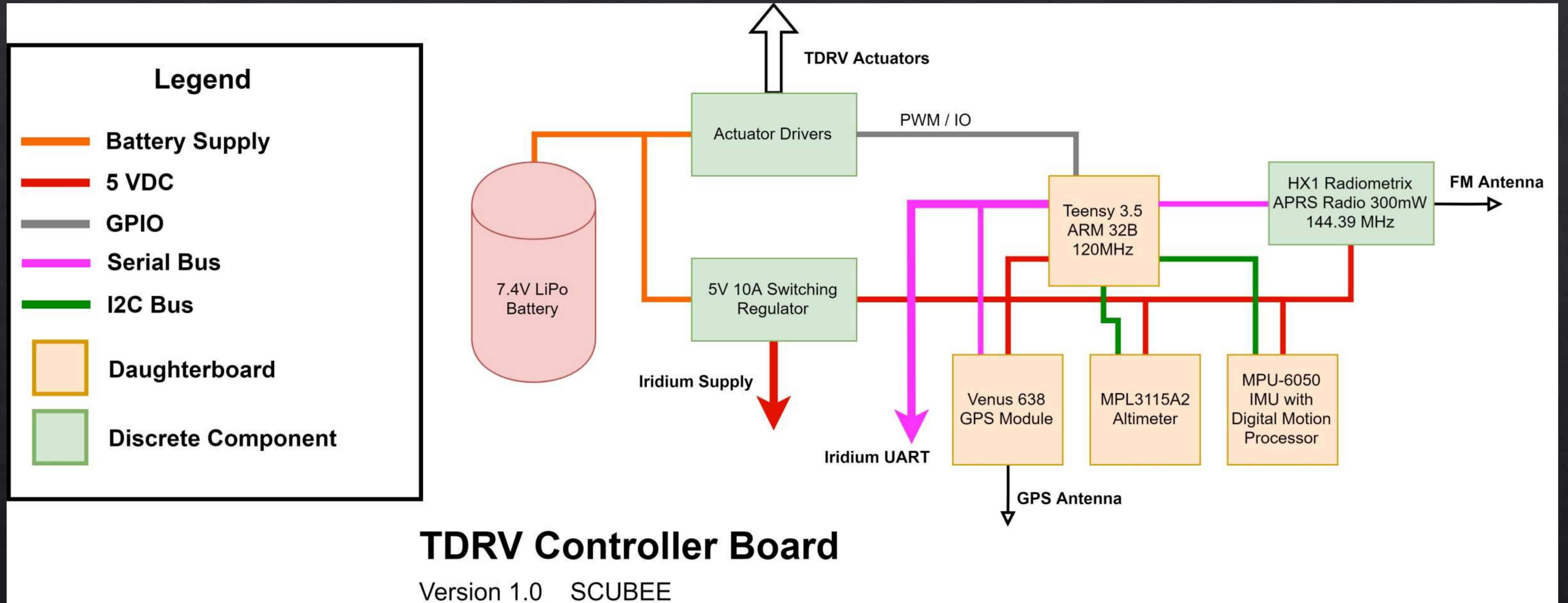
Flow Assembly.SLDASM [Drag free fall 120 mph [Default]]									
Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value	Progress [%]	Use In Convergence	Delta	Criteria
GG Force (Y) 1	[lbf]	-50.368345	-45.17135361	-50.368345	-39.35048364	100	Yes	5.134318356	5.746248661
Equation Goal 1	[lbf]	-0.035847535	-0.032148797	-0.035847535	-0.028006039	100	Yes	0.003654134	0.004089649
Iterations []: 81									
Analysis interval: 34									
rho =	.07775 lb/ft3		0.000045 (lb/in3)						
A =	53^(2/3)		14 in2						
Cd =			0.035847535						
Weight =			3.5 lb						
Terminal velocity									
v = sqrt(2*w/(Cd*rho*A))			556.7357317 in/s						
			31.6 mph						
			46.3 ft/s						

- The first spreadsheet represented iterations ACOM ran to determine C_d
- The second spreadsheet was a test our team ran to familiarize ourselves with the SolidWorks testing protocol

body assembly.SLDASM [Project(1) [Default(3)]]									
Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value	Progress [%]	Use In Convergence	Delta	Criteria
GG Force (X) 1	[lbf]	-18.07204481	-18.50522451	-19.02152156	-18.07204481	100	Yes	0.949476745	3.309087256
C_d	[]	-0.006042074	-0.0061869	-0.006359515	-0.006042074	100	Yes	0.000317441	0.001106336
Iterations []: 40									
Analysis interval: 20									

- 3 possible descent modes for future TDRV
 - Shell design with delayed opening of descent arrestor fins
 - Descent arrestors that immediately deploy
 - Descent arrestors along with a parachute deployed at lower altitude

TDRV Controller Diagram



Dual-design allows for use in TDRV and TDRV drop device
Drop device omits large regulator and IMU

Next Steps

Project Budget



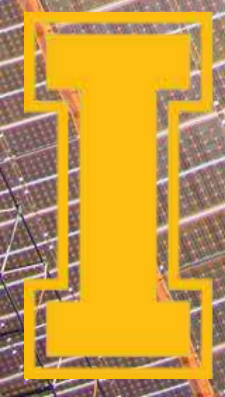
Project Budget												
Project:		NASA Ames-Suborbital Flight Communication										
Last Updated:		12/3/2018										
Expense Items	2018				2019					Item Total	Total Spent	Actual
	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May			
Iridium												
Iridium Data Plan				\$ 70	\$ 70	\$ 70	\$ 70	\$ 70			\$ 350	
PCB# 0				\$ 12							\$ 12	
PCB# 1					\$ 12						\$ 12	
PCB# 2						\$ 12					\$ 12	
PCB# 3							\$ 12				\$ 12	
PCB# 4								\$ 12			\$ 12	
PCB part#1					\$ 100						\$ 100	
PCB part#2					\$ 100						\$ 100	
LiPo battery					\$ 60						\$ 60	
Flight Control					\$ 30						\$ 30	
GPS and Iridium Antenna					\$ 30						\$ 30	
											\$ 770	Total Spent=
TDRV												
PCB# 0				\$ 12							\$ 12	
PCB# 0 part				\$ 238							\$ 238	
PCB# 1					\$ 12						\$ 12	
PCB# 1 part					\$ 238						\$ 238	
PCB# 2						\$ 12					\$ 12	
PCB# 2 part						\$ 238					\$ 238	
PCB# 3							\$ 12				\$ 12	
PCB# 3 part							\$ 238				\$ 238	
PCB#4								\$ 12			\$ 12	
PCB#4 part								\$ 238			\$ 238	
											\$ 1,238	Total Spent=
Launch(He)												
Parachute fabric					\$ 20						\$ 20	
Conductive fabric					\$ 30						\$ 30	
2 volt linear actuator					\$ 80						\$ 80	
											\$ 130	Total Spent=
Travel(4)												
Flight(4)								\$ 1,136			\$ 1,136	
Hotel(2 or 3rooms, 2 night)								\$ 440			\$ 440	
Rental Cars								\$ 363			\$ 363	
Per Diems								\$ 854			\$ 854	
Mileage								\$ 23			\$ 23	
Other											\$ -	
											\$ 1,680	Total Spent=
Moscow High School(\$1000)												we can get from last semester
Supplies Sent from Ames												
Assembly Bits												
Solder: Esoner 60/40 .031" diameter					\$ 5						\$ 5	
Solder Paste: MG Chemical 60/40 no clean 35g syringe					\$ 21						\$ 21	
Solder Wick: NTE Electronics SW22-10 3/16 blue					\$ 6						\$ 6	
Solder Tip: WEDB1 1.02" low conical tip					\$ 4						\$ 4	
											\$ 36	
Totals											\$ 5,002	
											\$	\$ (5,002)
											Budget	Excess



SPACE COMMUNICATION UTILIZING BACKBONE EXISTING NETWORKS

SCUBEE

Preliminary Design Review
December 2018



University of Idaho
College of Engineering

