ALASKA VEHICLE TEST \ FINAL REPORT

ZERO SOUTH Polar Traverse Vehicle convoy on the frozen Beaufort Sea. While in Alaska, the vehicles traveled a distance of 539 miles on paved roads, 514 miles on snow/gravel, 4 miles on solid ice road and 138 miles on sea ice (pictured above). (Photo by Richard Tukle)

This report has been prepared for the ZERO SOUTH team and includes information required by the State of Alaska, Department of Natural Resources, in response to LAS-30762 Stipulation 25, submission of a completion report

a. Actual Routes of Travel and Distances
b. Geographic data of the locations
c. List of vehicles used for off-road travel
d. Statement of debris cleanup activities and methods of disposal
e. Known incidents of damage to tundra

WITH SPECIAL THANKS TO THE RODDENBERRY FOUNDATION: Rod Roddenberry, Lior Ipp and Mica Krayzman; STATE OF ALASKA, DEPARTMENT OF NATURAL RESOURCES: Sean Willison, Melissa Head and Kimberley Maher; BUREAU OF LAND MANAGEMENT: Stacie McIntosh and Donna Wixon; K&N ENGINEERING: Steve Rogers, Steve Williams, Dan Chutes, Randy Harris, Jesse Spungin and Mary Brnca; MATTRACKS: Glen Brazier, Dan Laux and Jeremy Reese; ESPAR: John Dennehy; TOTE MARITIME: Cliff Hall and Kristy Boxx; CONOCOPHILLIPS: Jeremy Hartley, Wayne Vanderbilt and Lisa Pekich, NORTHSTAR: Jeff Bentz, Scott Vierra, Steve Black, Brad Robertson, Micah Goocey, George Nelson, Ty Calvin, Rick Noggle, Chris Vernon, Connor Irvine, Mike Harris and Brian Wiita; CARLILE TRANSPORTATION: Bobby Fontenot, Chris Bristow, Jeremy Miller, Jeremy Davenport and Kevin Sibley; PRUDHOE BAY HOTEL: Phillip Taylor; ARNIE'S NORTH SLOPE CARGO: Arnold Arey, Richard Tukle and Cyrus Nukapigak; BP: Carey Kyndall; CAELUS ENERGY: Dale Hoffman; NORTH SLOPE BOROUGH: Quincy Adams and Josie Kaleak; THE ZERO SOUTH ALASKA EXPEDITION TEAM: Nick Baggarly, Todd Borgie, Sherman Hon, Jonathan Knowles, Doug Pape, Rod Roddenberry, Rodney Wilson, Brock Winberg and Charlie Zacarias; THE ZERO SOUTH DOMESTIC SUPPORT TEAM AND VEHICLE INTEGRATION TEAM: Pat Young, Jim Nagashima, Erik Hatch, Mike Sabbarese, Joe Buechler, Tom Wagner and Jennifer Sims, Adrianna Perez Dave Lovejoy, John Dickerson, P.L. Questad, Noah Watenmaker, Thao Pham, Cole Winberg, Zane Winberg. With special thanks to John Millard, Chris Baumgartner and to Jerry Benson for introducing the idea of this Alaska test and pushing us to commit proper time and budget to the effort.

Table of Contents

FOREWORD

April 22, 2016

I am often surprised by how much energy I have for this project and how it rarely seems like "work" to work on ZERO SOUTH. Few things in life have come close to the sense of purpose it gives me, and I believe the reason for that is simple... we are on to something big.

Since the beginning, I have had only four or five bad days which is pretty good in the grand view, and that says a lot about this project. And even on these days, all I had to do to perk up my mood was hop in one of the vehicles and go for a spin. Whenever we bring the vehicles out there is overwhelming support and excitement for ZERO SOUTH that is electrifying and validating. It reminds us how special this project is. One of the greatest experiences for me came recently on our Alaska expedition when I witnessed members of our team experience this for the first time. Now, I can just look at the cover photo on this report or at one of the many team photos we took and instantly see beyond any difficulties.

It has been two months since our return and much was learned. While writing this report, I was reminded that the core purpose of ZERO SOUTH--as it was conceived many years ago--has not changed. The idea for this project came in 2005 before climate issues were generally accepted, and as time goes on the idea of combining new vehicle technology with fascinating people and places--as a broad-reach literacy program for climate science--continues to be a good idea that invites new audiences to understand the issues we face and get involved. Until recently, it was thought our audience would be gear heads, geeks and students. After all, these are the folks we ask, "hey, what kind of car should I buy?" But one takeaway from Alaska is that ZERO SOUTH will reach audiences we never imagined.

It is important to communicate our progress but these days there's so much noise, I prefer to talk when something is really happening. Finally, after so many years of development we have something to talk about. We completed an expedition in Alaska and I want to share what we saw and learned with you. The audience for this report goes beyond our dedicated, nine-member expedition team that went to Alaska. This account will be shared with future team members, our sponsors and a growing community of supporters who over the years made ZERO SOUTH possible. There are companies, foundations and many individuals who have literally swooped in to catapult this project forward despite recessions or difficult times. They are our project ***drivers***--the special ones who just show up and say, "let's get to work"--bringing funding or expertise that doesn't just keep us afloat but allows us to make progress. It is no fun keeping a project on life support. Instead, we like to make progress so, to this group of ***drivers***, I dedicate this report and hope it shows that your contributions are coming to fruition.

This account may seem too detailed to many of you; however, the details are important. They allow us to convey our experience to future expedition teams to help set their expectations.

One of our principles at Drive Around the world is, *be knowledgeable.* We value broad communication of the finest details and a general propensity for being over prepared--because that is the stuff that wins expeditions. The Norwegian explorer, Amundsen knew this too well. He lived with Inuit tribes for years while preparing for his South Pole expedition and because of it, he was the first to get there. At Drive Around the World, we share Amundsen's definition of "prepare" and strive to get better at it. No matter how long it takes, we will go to Antarctica... and when we do, we'll be prepared.

If there is one takeaway I wish for anyone connected to ZERO SOUTH it is this: You can do almost anything you set your mind to as long as you persevere. My dad always talks about perseverance preferring instead the quasi-word, *sticktoitovness* (which is such a funny word) but I have grown to realize that almost anything can happen with this quality. Just remember, world-changing projects take time to unfold.

Finally, more people are seeing a need for projects like ZERO SOUTH. There is a resilience to our work as each day environmental themes become more relevant and timely. We knew this in 2005 but it was fascinating to see it first hand in Alaska. The following pages cover these experiences which were overall, successful and positive.

Our next phase is an exciting one that we are calling, South Pole Readiness. It will take three months at a cost of $100,000 to re-stage the project for Antarctica and incorporate many of the vehicle fixes, enhancements and lessons described in this report. Once this is done, our entire expedition kit--the vehicles, sleds, gear, spare parts--everything-- will be ready for Antarctica. The final steps are to build and train an expert Antarctica team and raise the **Project Completion Fund**--or **PCF** as I am calling it-- which is the final round of production capital required to travel to Antarctica.

The Alaska test exposed mechanical weaknesses which are EASILY rectifiable in the next project phase. If you support ZERO SOUTH now it will have a leveraging effect: a small amount now will bring greater gains than ever before in the history of this project. We have conquered our biggest challenge to date--a real time test. It was the most exciting thing we have ever done. Now, we are in the final sprint to the finish line.

Expeditions are always more than you bargain for and Alaska was no different. As I write this I must tell you that ZERO SOUTH is at a critical stage in its lifecycle. The **South Pole Readiness** phase must begin immediately to make this year's window for Antarctica possible and mobilize public support for climate initiatives. I invite you to join our elite team of ***drivers*** who are making ZERO SOUTH happen. Simply contact me if you would like to help.

Best wishes from the ZERO SOUTH team. We appreciate your continuing support.

Project Name	**ZERO SOUTH**
Expedition	**Alaska Vehicle Test Expedition**
	(aka OPERATION : FROSTY; ZERO SOUTH 7117 Expedition)
Dates	**January 24, 2016 to February 19, 2016**
Duration	**27 days (vehicle door to door in 46 days)**
Distance	**1,187 miles**

An undated NASA illustration shows Arctic sea ice at a record low wintertime maximum extent for the second straight year, according to scientists at the NASA-supported National Snow and Ice Data Center (NSIDC). At 5.607 million square miles, the Arctic sea ice is the lowest maximum extent in the satellite record, and 431,000 square miles below the 1981 to 2010 average maximum extent. (Photo courtesy of NASA)

THE ZERO SOUTH PROJECT

ZERO SOUTH is "citizen science on steroids" and a non-profit program developed by Drive Around the World, Inc. It is supported by 50 sponsors and 50 individuals who make up a volunteer workforce, with each member bringing highly-specialized talents and expertise that the project needs. Concerned about environmental issues, a group of Los Angeles-based mechanics and engineers formed a team in February 2009 and met on Tuesday evenings for six years to build two hybrid-electric, science-support vehicles. Following testing, the vehicles will be used by scientists to answer important questions about human and non-human impacts to Earth's climate as the central theme for a multi-season television series entitled, ZERO SOUTH. The volunteer team, combined with trickle-in resources, makes for an unconventional program; however, the project endures due to a strong vision and the sustained efforts of a dedicated team.

ALASKA VEHICLE TEST EXPEDITION : PURPOSE AND AIM

The purpose of the Alaska Expedition was to test two experimental, hybrid-electric Polar Traverse Vehicles (HE-PTVs) that will be used for future science efforts in Antarctica. A test drive across the North Slope of Alaska from Prudhoe Bay to Barrow using two ZERO SOUTH vehicles and one Airstream habitat sled (herein referred to as, *the SnowStream*) provided an opportunity to obtain real-world data and

experiences related to extreme-low temperatures, towing and a variety of terrain surfaces that are similar to what will be encountered in Antarctica. The ZERO SOUTH vehicles were designed and built to operate in extreme-cold environments so a "real-world" test in Alaska was conceived as a precursor for an upcoming traverse across Antarctica. The Alaska activity represented the fourth of six testing milestones to prepare the vehicles for use by scientists in some of our planet's coldest regions. The journey was made possible through a grant from The Roddenberry Foundation.

EXPEDITION TEAM

The ZERO SOUTH Alaska Expedition Team consisted the following individuals serving multiple roles.

#1 **Nick Baggarly** *Expedition Leader; Ocean and Road Shipping Logistics Coordinator; Expedition Equipment and Inventory Coordinator, Vehicle Engineer; Driver*
#2 **Todd Borgie** *Accommodations Coordinator; Personal Gear Rental Coordinator; Vehicle Mechanic; School Visits Coordinator; Vehicle Cameras Coordinator; Driver*
#3 **Sherman Hon** *Vehicle Engineer; Navigator; Test Plan Coordinator; Airfare Coordinator; Driver*
#4 **Jonathan Knowles** *PR Coordinator; School Visits Coordinator; Science Coordinator; Driver*
#5 **Doug Pape** *Personal Gear and Rigging Coordinator; Guide and Site Garages Coordinator; Barrow Contacts Coordinator; Vehicle and Team Security; Anchorage Advance team; Driver*
#6 **Rod Roddenberry** *Social Media Coordinator; Vehicle Cameras Coordinator; Science Coordinator; Driver*
#7 **Rodney Wilson** *Emergency Communications, Contacts and Equipment Coordinator; Culinary Captain (hot water production); Caffeine Coordinator; Driver*
#8 **Brock Winberg** *Vehicle Engineer; Vehicle Mechanic; Vehicle and Trailer Rentals Coordinator; Drone Pilot; Driver*
#9 **Charlie Zacarias** *Vehicle Maintenance Coordinator, Vehicle Mechanic; Driver*

The group was supported by the Drive Around the World's Domestic Support Team (DST) to provide remote lifelines if called upon. The DST members were, Pat Young, Jim Nagashima, Mike Sabbarese and Bernard Juchli, with 50 representatives from vehicle sponsors and technology suppliers.

The ZERO SOUTH Alaska Expedition Team. FROM LEFT: Rodney Wilson, Nick Baggarly, Sherman Hon, Brock Winberg, Charlie Zacarias, Rod Roddenberry, Douu Pape, Todd Borgie and Jonathan Knowles. (Photo by Jonathan Knowles)

VEHICLES USED

Two ZERO SOUTH Hybrid-Electric Polar Traverse Vehicles were used along with one Dodge 1-ton guide vehicle and one Chevy 3/4 ton support vehicle. Complete specifications for the two PTVs are available here.

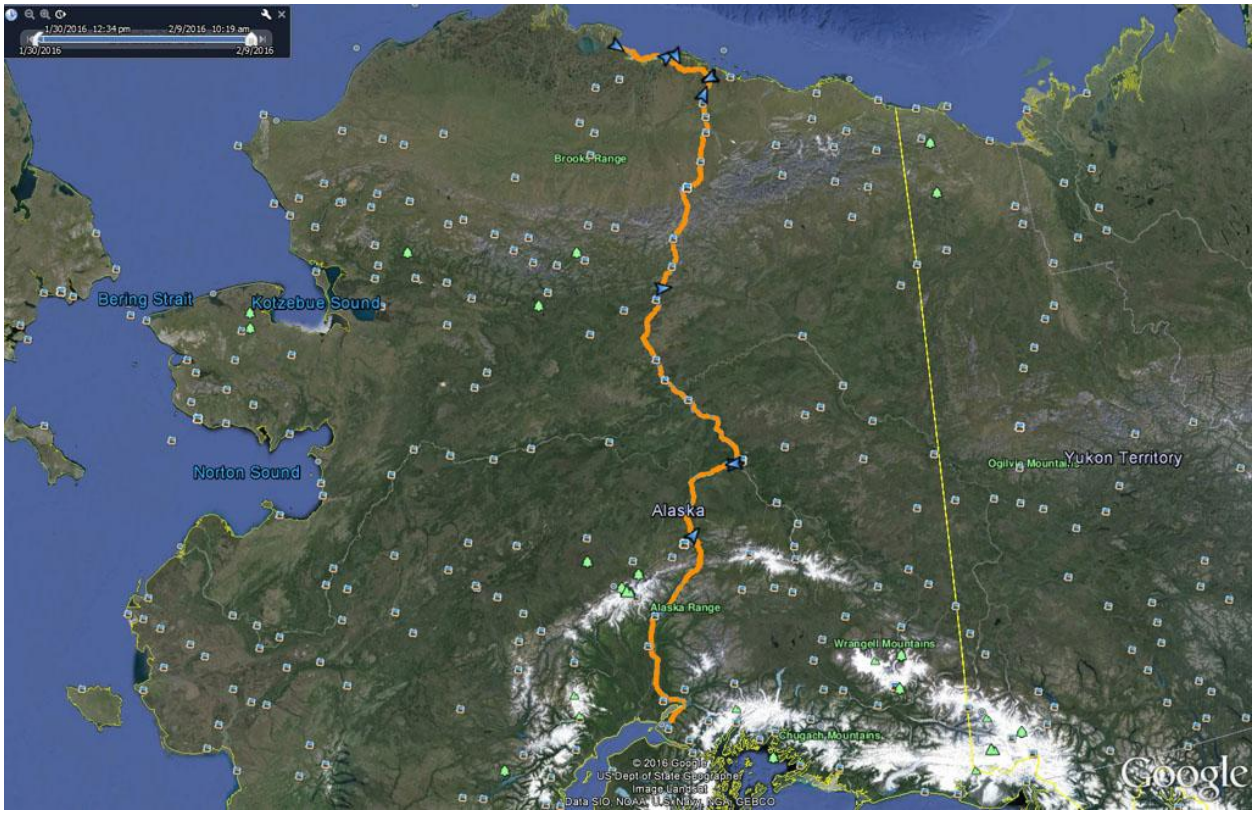
PERMITS, ACCESS AND PERMISSIONS

Vehicle testing in Alaska was conducted after securing permits from the Town of Barrow, North Slope Borough (NSB 16-346), State of Alaska Department of Natural Resources (LAS 30762), State of Alaska Department of Fish and Game (FH16-III-0014), United States Bureau of Land Management, and with support from Tote Maritime, Carlile Transportation, North Star, BP, ConocoPhillips, Caelus Energy, Mattracks, Alaska Trailer Rentals and Alaska LED Industries. In total, the permit process involved coordination with twelve organizations and approximately 75 individuals outside the ZERO SOUTH team.

DISTANCE TRAVELED

Due to inherent dangers involved with driving on a frozen sea, it was decided that an endurance test should occur on paved and snow/gravel roads prior to the sea-ice portion of the traverse to shake out any issues with the vehicles. This took place by way of an 953-mile drive from Anchorage to Prudhoe Bay on tires. This phase of the expedition was productive and resulted in remediation of numerous issues. The total distance driven of 1,187 miles is a few miles shy of the expected distance for Antarctica.

ROUTES TRAVELED



The ZERO SOUTH Alaska Expedition Route: Using three sources, team Navigator Sherman Hon produced a complete GPS track of the expedition that continuously recorded throughout the Alaska tour. Geographic Data containing actual routes of travel, distances and locations is available in a GPX file which can be opened from within Google Earth or other GPS tools.

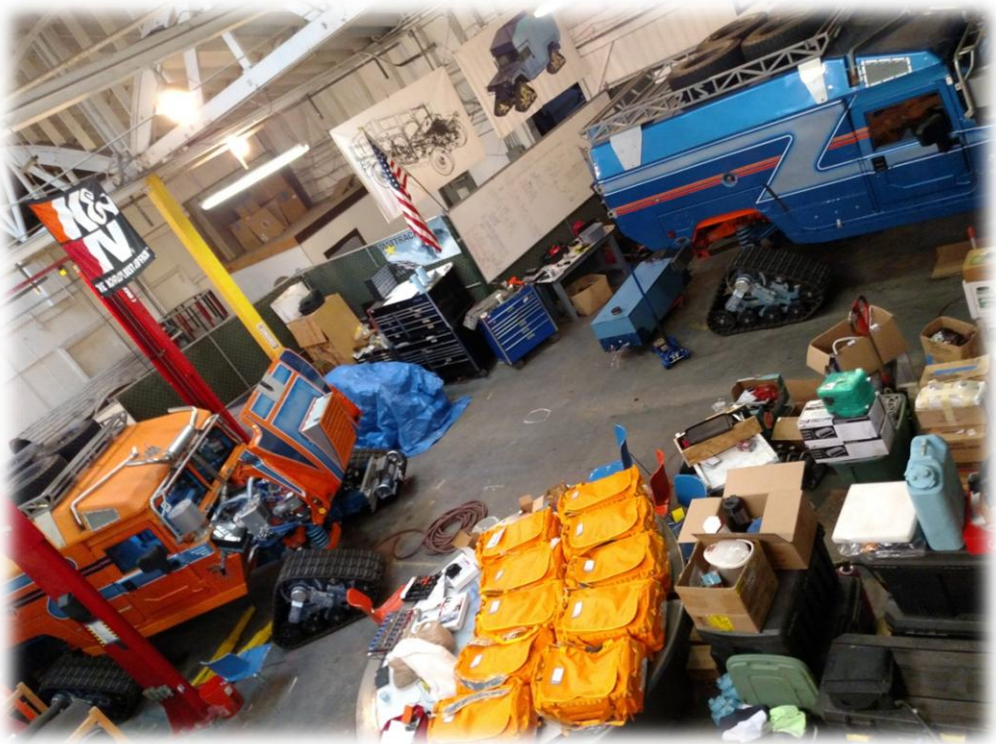
SURFACES TRAVELED

Start/End	Surface	Distance on surface	Odometer Reading (PTV1)
Anchorage odometer reset			0
Anchorage to start of Dalton Highway	Paved	539	539
Dalton Highway to Deadhorse	snow/gravel	414	414
odometer at Deadhorse arrival			953
Deadhorse to Oliktok Point	snow/gravel	50	1003
odometer at Oliktok Point arrival			1003
Oliktok Point to Harrison Bay (farthest point west) and back to OOOGURUK Island	sea ice	134	1137
OOOGURUK Island to Prudhoe Road System	solid ice	4	1141
odometer upon return to Deadhorse	snow/gravel	50	1191

EXPEDITION PHASE 1 : PREPARATION AND SHIPPING

PREPARATIONS IN LOS ANGELES

Vehicle shipping to Alaska represented Phase 1 of the expedition. Prior to shipping from Los Angeles, a formidable scope of work was completed over the course of two months to prepare vehicles and equipment for the journey. The individuals primarily responsible for expedition preparation were Nick Baggarly, Joe Buechler, Kevin Buechler, Sherman Hon, Mike Sabbarese, Rodney Wilson, Brock Winberg, Brandon Ybarra, Pat Young and Charlie Zacarias with considerable support from Jennifer Sims, Adrianna Perez and staff at Big Art Labs.



Vehicle preparations at the ZERO SOUTH Vehicle Integration Facility, Big Art Labs, Los Angeles, CA (Photo by Charlie Zacarias)

Team members were permitted to bring a backpack and two large duffle bags, one of which contained extreme-cold-weather gear and standard-issue items supplied by Drive Around the World. (Photo by Brock Winberg)

VEHICLE AND TEAM SHIPPING - LOS ANGELES TO ANCHORAGE

On Sunday, January 17th 2016, all vehicles were loaded in Los Angeles and lashed to a 48 ft step deck trailer under the proprietorship of Idaho-based, Northwest Salvage and Recovery. The vehicles traveled by road to Tacoma, Washington and arrived two days later.

The ZERO SOUTH PTVs and SnowStream after loading onto a 48-foot step deck trailer. Careful measurements and calculations were made to determine whether it was possible to ship the entire expedition kit on a single truck. We learned that considerable oversight is necessary when loading or unloading. (Photo by Charlie Zacarias)

On January 19th, vehicles were transferred onto two 40 foot trailers and lashed for ocean shipping from Tacoma to Anchorage. The trailer containing the vehicles was loaded aboard Tote Maritime's vessel, *Midnight Sun* which sailed the following day on voyage 16009. The trailer containing the SnowStream sled was rejected by longshoremen for being oversized due to recent voyage cancellations which required the shipper to use this space for perishable cargo. So in essence, the expedition kit was now split up. This became the source of a problem that would put the expedition one week behind schedule and put the team to the test at very beginning of their journey.

VEHICLE TRANSFER AND LASHING

Eight transfer and lashing phases took place during the expedition, where observation resulted in several important lessons learned. During the northbound road segment to Tacoma, PTV1 nearly fell off the truck because it was lashed improperly with straps. The truck hit a large bump causing the front end of the vehicle to lift and come down (fortunately in the same position) with tracks turned 40 degrees. The driver stopped to secure the load but, for this reason, all future transfer and lashing operations must be strictly overseen by a qualified rigger with these requirements: 1. use chain and chain binders as the primary means of lashing the vehicle. 2. chains must go around all four lower control arms. 3. individual straps must go through each track and these straps should be fastened to the trailer's adjustable side latches. 4. wood or plastic wedge pieces should be nailed to the deck in front of and behind each track. 5. additional fore and aft straps are a good idea in case a chain breaks.

Observations made during three of eight vehicle transfers resulted in new methods for securing the ZERO SOUTH PTVs for transport. (Photos by Nick Baggarly)

PREPARATIONS IN ANCHORAGE

On Sunday, January 24, members of the ZERO SOUTH Advance Team arrived in Anchorage by air. Remaining members arrived on Tuesday, January 26.

On January 26, Tote Maritime's *Midnight Sun* arrived at the Port of Anchorage. The following day, the trailer containing the two ZERO SOUTH vehicles was delivered to North Star Terminal who generously provided a heated garage to prepare the vehicles and stage equipment for the long drive north. It was at this time the team received news that the Snowstream sled did not arrive. Several members of the team had strict schedule commitments beyond February 9 so the shipping delay threatened to cancel the expedition, but after discussing the situation, Tote Maritime agreed to provide roundtrip shipping for the sled to Prudhoe Bay at no charge. This allowed the 860-mile drive to Prudhoe Bay to begin with an unanticipated benefit that the PTVs would not have to tow trailers up the Dalton Highway.

Several days were spent in Anchorage performing maintenance and producing wheel well panels to protect the engine bay and high-voltage systems from ingress of snow and road debris. All team

members participated in these preparations and considerable time was also spent sourcing cold-weather gear, in-vehicle cameras, spare parts and consumables. This was necessary since the majority of spare parts, and much of the team's gear, was shipped inside the SnowStream, and thus unavailable.

The vehicles were eventually switched from tracks to tires for the drive North. Before doing so, Sherman Hon enabled logging on the PTV GPS units and reset the odometers. Then, the entire team took the vehicles for a drive through downtown Anchorage and an overwhelming public response was received with many inquiries from passersby, which was a validating experience. The ZERO SOUTH vehicles were built to operate in the Antarctic summer where near-constant 24 hour sunlight exists; however, the Alaska test took place in the northern hemisphere during mid winter, where less than six hours of daylight occurs each day, so two high-intensity LED light bars were sourced from Alaska LED Industries. Other pre-departure items included: battery system checks and optimization, dressing wiring as necessary and the installation of additional insulation.

The ZERO SOUITH Alaska Expedition Team staging in Anchorage. (Photo by Rod Roddenberry)

Team member Brock Winberg saw the need for additional lighting and took initiative to obtain a high-intensity LED light bars from Alaska LED Industries. The drive north would not have been possible without them. (Photo by Sherman Hon)

Both PTVs on the dock in Anchorage shortly after unloading. (Photo by Brock Winberg)

EXPEDITION PHASE 2 : DRIVING NORTH THROUGH ALASKA

SNOW, ELEMENTS AND ROAD CONDITIONS

Winter is a good time to drive the Dalton Highway since road conditions are smooth due to snowplow grooming that occurs after new snowfall. During the last 200 miles of the drive to Deadhorse, we were caught in a Phase 2 storm where temperatures hit -40°F and a constant wind gust of 20 MPH reduced visibility at times to 10 feet or less. The Dalton Highway has raised road markers spaced every 10 yards and without them we would not have been able to continue. The LED light bars illuminated the road markers so we could see well enough to travel and avoid snow drifts, however the limited visibility restricted speeds to 5 to 15 MPH. Road signs were usually good but many signs north of Coldfoot were caked with snow and could not be read. Before leaving, the PDU, Battery Box, and inverters were sealed up. The rear inverter is in a bad spot for water but no issues occurred. The make-shift wheel well panels did better than expected, keeping dirt, mud and snow out of the engine bay.

THERMAL SYSTEM

One of the major questions going into the expedition was, “will the thermal system work”? Although the components had been unit tested, we had no real experience with the heat generation and transfer capabilities of the system in weather below 20°F. It's job, to keep components warm while at idle, to rapidly heat components after extended periods of deep freeze, and to cool them while underway (because at that point they generate their own heat) is a tough one. Would it be able to keep the batteries warm, and how long would it take to preheat the batteries from below zero to operational temperatures? These questions were answered on the road between Anchorage and Deadhorse and, in essence, the system worked very well--even shockingly (pun intended) well. It was able to preheat the batteries from -10°C to above 0°C--which is the minimum operating temperature--in about an hour, and the battery box insulation performed its job of keeping the heat in. Sherman Hon, our Battery Chemist, was pleased with the thermal system, and to our surprise it required less manual input than anticipated. All engineers and mechanics did a superb job of monitoring the vehicle vitals, discussing anomalies and quickly responding to problems. They were all aware that a single blown hose could cause a component to heat up and break but this was not going to happen on their watch.

ENGINE POWER AND RPM

The engine and generator performed well and had no major issues throughout the expedition however the main engine reporting display screen that registers engine temp and oil pressure stopped working so Brock Winberg and Sherman Hon ran a thermocouple wire to the engine block and used a portable monitor to keep an eye on engine temps. Just after Atigun Pass, Winberg and Hon experimented with Engine RPM optimization and found that on relatively level surfaces they were able to operate at 1400-1700 RPM which was much quieter in the cab, reducing the ambient noise by about 50% and making it easier to communicate. The addition of more insulation, padding and sound deadening material as a means to reduce engine noise and retain heat will go a long way for passenger well being.

BRAKING

We know from past excursions through the White Mountains and the Grapevine that our brakes can heat up and lose their effectiveness, so this was something we watched closely while traveling the Dalton Highway. The 414-mile stretch included dozens of steep downhill grades at 6% to 10% and a few at 11% and even 12%, so the convoy was required to travel at ultra-low speeds through these areas. Sherman Hon and Todd Borgie researched the route in advance and produced a condensed datasheet on the Dalton Highway. They notified the convoy when the steepest grades were approaching. PTV1 dislodged one of its rear brake calipers which had been installed with an incorrect length bolt. The correct size bolts were sourced and all incorrect bolts were replaced. Additional braking issues are listed below in the Vehicle Issues List.

POWER STEERING ISSUES

The drive to the top of Alaska was interrupted frequently with power steering problems. The belts would break and this in turn would compromise the alternator belts which had to be replaced as well though not as often. Each PTV has two alternators driven off a single, six-rib serpentine belt and a performance, power steering pump that features high capacity and high pressure flow. We learned that running the engine at a lower RPM preserved the life of the power steering belt. PTV2's power steering belts rarely had to be changed but this was done several times as a preventative measure. PTV1 could not go more than a day without breaking a steering belt. Knowing that spares availability in higher Alaska latitudes would be scarce, it became such a concern that we sent the team to auto parts store in Fairbanks to buy every belt they had that could conceivably fit. A four-rib belt was tried and it lasted much longer. A failure analysis should occur with the power steering system and a new, lower pressure, belt-driven pump should be considered. Problems were also experienced with the electric power steering system. Just outside Anchorage the power steering belt on PTV1 broke and when electric power steering was engaged, the pump did not come on. Investigation revealed it stopped working due to a bad Tycho relay in the relay fuse box. Another issue came later when we discovered the main output port (which was a press in fitting) came out-likely due to cold. This was discouraging because the pump was new. A new style of EHPS pump should also be considered and a proposal to remove the belt driven pump all together in favor of a sole electric pump and spares should also be considered.

RADIOS AND COMMUNICATION

New, longer radio antennas were added to improve range; however, only two range tests were performed. The first was in Fairbanks where transmissions greater than three miles away could be heard. The second test was about ten miles out of Coldfoot when one of the PTVs ran low on power steering fluid so our chase truck was sent into town and later confirmed receipt of transmissions from ten miles away. Both PTV radios experience occasional intermittent failures that would causes all of the channel buttons to flash. Power cycling the radio fixes the problem but the cause is unknown and should be researched.

Team member Brock Winberg came up with the best formula for estimating how long it will take the ZERO SOUTH vehicles to reach any given destination. "Just estimate how long it takes a regular car and double it." (Photo by Sherman Hon)

PREPARATIONS IN DEADHORSE

On February 1, Tote Maritime's *North Star* voyage 16003 arrived in Anchorage and with it, the SnowStream sled. Once offloaded, it was hitched to a Carlile tractor and trucked 860-miles and to Deadhorse and delivered on February 4, one day ahead of the team's arrival.

On Wednesday, February 3, the nine-member team reached the end of the Dalton Highway and rolled into the town of Deadhorse, completing a 953-mile drive to the top of Alaska. They began staging for the next, and most important, phase of the expedition--a 410-mile roundtrip traverse from Prudhoe Bay to Barrow. As mentioned, the team arrived during a Phase 2 storm. On the North Slope of Alaska, storms are measured by intensity with Phase 1 being the smallest, and only necessary road travel is permitted, and Phase 3 being the most intense, calling for a complete field shutdown where all workers are recalled indoors and only emergency, escorted travel is permitted. The team drove through the storm and observed a buildup of snow inside the vehicle due to small gaps around door seals and hinges. A 30MPH west wind was blasting against the passenger door which eventually forced Sherman Hon to take refuge in the back. Since there were no markers on the sea ice, the cautious thing for our team to do was to wait out the storm. Team members were asked to pack their bags and talk with locals about the weather and seek local weather reports so we would know the duration and intensity of any upcoming storms and the sea ice conditions. This information was key to knowing when we could safely launch from our point of embarkation onto sea ice at Oliktok Point which was 55 miles away.

Carlile Transportation supported the program with space inside a heated garage in Deadhorse where the team performed maintenance and numerous pre-expedition preparations. The plan was to perform all work on vehicles and prepare the gear so we could drive to Oliktok Point, switch the vehicles to tracks, hitch the SnowStream sled and begin the sea ice portion of the drive to Barrow. Over the next two days, the team prepared a subset of tools specific to track installation and other pre-launch tasks, then packed

and lashed the vehicles so they were ready to go. Schedule pressures, a sizable TO-DO list and a last-minute difficulty with insurance became stressors so the team was reminded to keep a good attitude despite the uncertainty. Often times with delays a "hurry up and wait" attitude sets in but there are always things one can do. Several team members who had signed up for the one week schedule were asked to decide whether they would make the drive to Barrow so we could know what team resources we could count on. Team members Knowles and Borgie, who were already several days beyond their commitment, announced decisions to return to California although both stayed on for an additional 48 hours to help with departure preparations.

The surfaces anticipated for the remaining journey were estimated at 110 miles of private snow/gravel roads throughout the Prudhoe road system and 300 miles of sea ice for the round trip between Oliktok Point and Barrow. Prior to arrival, ZERO SOUTH signed a Road Use Agreement with ConocoPhillips, permitting travel within the Prudhoe road system and the State of Alaska Department of Natural Resources provided General Winter Off-Road Driving Rules to observe within the Prudhoe road system. Information from these documents should be collected and observed on all future ZERO SOUTH programs and added to ZERO SOUTH training guides.

GEAR DRESS REHEARSAL

On the evening of Thursday, February 4, the team held a meeting to review vehicle status, driving rules and departure plans. At this meeting, gear expert, Doug Pape introduced the idea of an extreme-cold-weather dress rehearsal that required all members to outfit in full expedition gear and take a walk around Deadhorse to become familiar with gear and the elements. All members commenced the outdoor exercise which was very helpful and should be repeated in future field programs. The exercise helped team members identify vulnerabilities in their gear, discuss solutions and address issues prior to going out to the ice. The team learned one of its members was celebrating a birthday and concluded the evening with a mysterious appearance by a rarely-seen inhabitant of the Alaskan North Slope.

ZERO SOUTH Alaska Expedition Team. FROM LEFT: Sherman Hon, Rod Roddenberry, Brock Winberg, Jonathan Knowles, Charlie Zacarias, Yeti, Rodney Wilson, Douu Pape, Todd Borgie
(Photo by R. Roddenberry)

Team member, Rod Roddenberry celebrates his birthday posing in a rare photo with AGOR-GAR, 1st District Representative, North Slope Yeti Community.

EXPEDITION PHASE 3 : PRUDHOE BAY TO BARROW

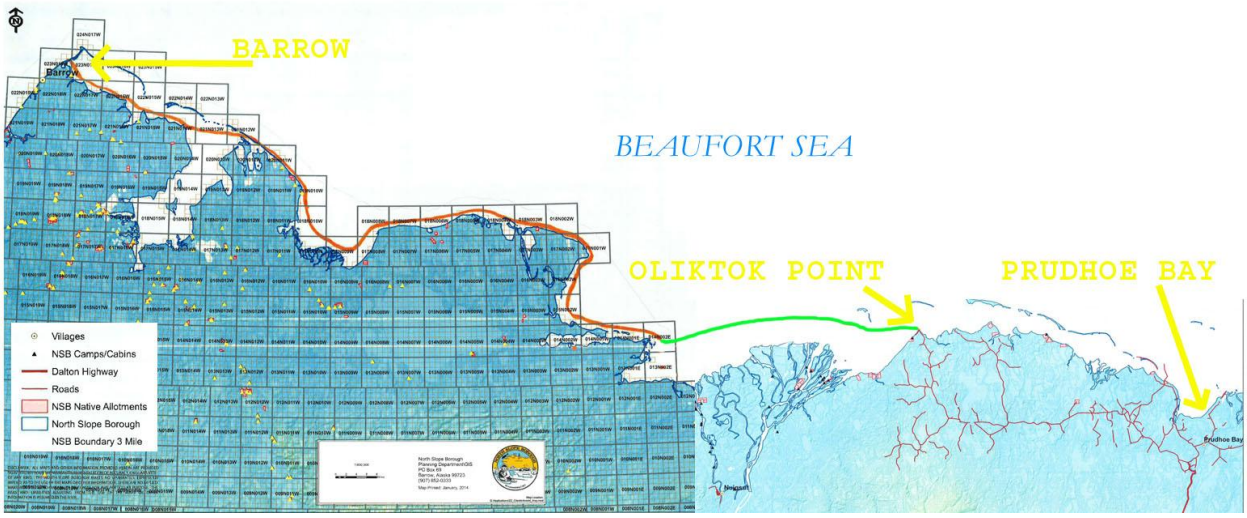
On Friday February 5, two members of the ZERO SOUTH advance team, Todd Borgie and Jonathan Knowles, flew home due to prior commitments and Vehicle Engineer, Brock Winberg flew home due to a family emergency. On Saturday, February 6 at 15:30 hours, with two PTVs and one support vehicle pulling an enclosed trailer, the remaining team consisting of Nick Baggarly, Sherman Hon, Doug Pape, Rod Roddenberry, Rodney Wilson and Charlie Zacarias drove through the BP gate and entered the Prudhoe road system, beginning phase three of the expedition. The team stopped in Kuparuk to meet with ConocoPhillips representative, Jeremy Hartley who accompanied them to the expedition staging area designated at Oliktok Point. Among the goals for the expedition was a test of the vehicles in a variety of situations including, over-snow towing, traction on snow and ice surfaces and gathering performance data to assess over-snow mileage and range for the PTVs while towing versus non-towing. As Sherman Hon put it best, "essentially, the drive itself is the test." Separate tests to measure the effectiveness of the SnowStream insulation, heating system and living facilities were additional objectives.

EMERGENCY CONTACT AND RESPONSE PLAN

A bi-directional-communication link was established between our team and Jeremy Hartley using a DeLorme InReach to receive daily weather reports or for emergencies. Following the meeting in Kuparuk, Baggarly insisted that full circle In-Reach communication with Jeremy Hartley be tested. In addition to designating an emergency contact and communication strategy, the team also carried a Paines Wessex emergency locator beacon, a flare gun, hand flares and hired a guide who was familiar with the routes and possessed several means to repel polar bear attacks. Extra levels of safety were achieved through inclusion of multiple vehicles, a guide vehicle (a Dodge truck with Mattracks and trailer) and ZERO SOUTH's 22-foot insulated/heated SnowStream sled which could serve as an emergency safe haven for the entire crew if needed.

OLIKTOK POINT STAGING AREA

The team reached Oliktok Point at 18:30 and began changing the PTVs from tires to tracks. We rendezvoused with our guide, Arnold Arey of Arnie's North Slope Cargo, along with his colleagues, Richard Tukle and Cyrus Nukapigak, who went to work changing their Dodge truck over to Mattracks. All vehicles were equipped with Mattracks and PTV2s roof rack carried a set of four tires in case they were required. Our guide's vehicle pulled a boat trailer and one Siglin sled. Simultaneously, representatives from ConocoPhillips offloaded the SnowStream sled onto the pad and eventually it was hitched to PTV2 allowing the first-ever break-out traction test and towed-load resistance test to be completed. The vehicle towed the sled with relative ease requiring the generator to make approximately 60 kW to get the sled moving across level, groomed snow surfaces. Eventually, our guide led us down the Oliktok boat ramp to begin the sea ice portion of the expedition. A video from the first moments on the ice is here.



(Map courtesy of North Slope Borough, Planning Department GIS)

Oliktok Point in summer. The ZERO SOUTH PTVs were prepared for the sea ice near a water treatment plant which served as a wind barrier during final preparations. (Photo provided by State of Alaska, Department of Natural Resources)

Team member, Rod Roddenberry prepares PTV2 for the ice by installing Mattracks at Oliktok Point. (Photo by Sherman Hon)

PTV2 moments before its maiden voyage onto sea ice. (Photo by Sherman Hon)

After many years of construction, the SnowStream was hitched to PTV2 and towed with ease for the first time. The vehicle generated 60kW towing across level, ungroomed snow surfaces. (Photo by Sherman Hon)

PTV2 on the ice at sunrise. Definitely the runner up for cover photo. (Photo by Sherman Hon)

DRIVING ON SNOW AND ICE

When driving on a vast expanse of frozen nothingness you might think you would put your vehicle on a heading to your next waypoint and just drive straight, but that was not the case. Our guide led the convoy in his Dodge vehicle and did not drive straight--preferring instead to forge a route that was more like a hunter, zig-zagging as he tracks an animal. Our guide taught us a lot. He was constantly scouting for trails and driving around ice cracks, ridges and snow drifts. His constant and intense attention to terrain is something to be adopted on future traverses.

THERMAL SYSTEM CALIBRATION AND PERFORMANCE

With Phase 3 of the expedition came additional understanding of the vehicle's thermal system. A goal of the expedition was to "dial in" the thermal system and develop pre-warming startup and shutdown procedures that are safe for the components they were designed to protect. On numerous mornings, system startup was conducted by early-riser-engineer, Brock Winberg who identified new ways to start the vehicle after approximately 10 hours of cold soak at temperatures around -20°F. The Espar hydronic heaters worked very well although a final intake/exhaust solution is still needed and both the hot and cold tank need temperature gauges in the cab. The heat exchanger also worked well to bring the cold tank up to temperature and once this was achieved, the battery pump would be enabled to begin warming the batteries. It took an average of 45 minutes to warm the batteries to 0°C (32°F), which was the temperature deemed acceptable before the Steyr engine/generator could be started since damage to the batteries will occur if charging takes place when their temperature is below 0°C. Once the batteries were above 0°C, the pumps for all inverters were enabled to warm the inverters above 0°C--however, the inverter warming step was often skipped and the inverters were frequently enabled at temps lower than 0°C. Once target temperatures were reached, the battery contactors could be closed and, by this time, the primary hydronic loop would have warmed up the Steyr engine block enough for it to be started. On several mornings, both hydronic heaters were run at the same time which seemed to speed things up, but this would consume considerable low-voltage power. We also had to remember to make sure the valve levers for the hydronic heaters were opened. The valve levers inside the cab should be labeled. The most impressive startup was on PTV2 after it spent three days on the ice cold soaking in -20°F. On this occasion, both hydronics were used however the low-voltage batteries were getting low so the high-voltage batteries were brought online and the DC/DCs were turned on to charge the low voltage batteries from the high voltage pack. This was useful and was deemed acceptable since the high-voltage batteries were being discharged only (discharge, at any temperature, will not harm the batteries). It also demonstrates the design flexibility of both low and high voltage battery systems and the thermal system. One other thing we noticed, after a night in a warm workshop, with the vehicle completely off (no hydronics running), PTV2's battery temperatures were greater than PTV1's which suggests that PTV2's battery box may be less insulated than PTV1's. (NOTE: after a day of driving in cold temperatures, PTV2's battery temperatures were consistently higher than PTV1's.)

VEHICLE IMMOBILIZATION

At 20:00 hours on February 7, approximately 40 miles into the sea ice drive, PTV2 sheared all of the studs on the left-rear spindle and dislodged its track. After examining the problem, Charlie Zacarias announced the vehicle could be repaired by taking one or two studs from each corner on both vehicles and this was done with all team members participating in the repair to some degree. Realizing this would fix the symptom and not the cause of the drive-line problem (which could become worse), the team decided to return to Oliktok Point. On the way back, approximately 10 miles east of this position, PTV2 suffered an unmendable immobilization when the same corner sheared its spindle causing the track to come off. Fortunately, it was held in place by its limit arm and remained with the vehicle and no damage to the wheel arch or fuel tank occurred. The location of the breakdown was in Harrison Bay just past the Colville delta at GPS position, North 70°, 32.970 minutes by West 151°, 47.286 minutes and a team photo was taken at this location. With the majority of the expedition test plan completed, and no repair parts on hand, the team decided to conclude the activity on the ice and leave the vehicle and return later to recover it. For future field operations, the team should devise a way of towing a vehicle with a broken corner.

EXPEDITION FAR POINT

ZERO SOUTH did not drive off-road on any tundra routes. Many locals requested that we be mindful if we did travel on tundra since it is very easy to damage. The expedition was destined for the town of

Barrow but made it only to Harrison Bay. Days after the expedition returned there were reports that strong winds had pushed the ice out of Barrow and where it was ordinarily frozen solid, there was only open water as far as the eye could see. Had the expedition continued it might have encountered open water and definitely would have required Tundra travel for the final miles. There were also reports that the ice had been pushed further north than in previous years and this occurred much sooner than in previous years. Many locals shared opinions about climate change and how temperatures and ice flows are being affected in the Arctic. Most were unsure whether these changes are manmade or naturally caused. Some locals reported that there is hardly any snow on the Tundra this season.

The ZERO SOUTH Alaska expedition traveled approximately 50 miles west of Oliktok Point and reached Harrison Bay just beyond the Colville River delta. (Map courtesy of Caelus Energy)

ZERO SOUTH 7117 Expedition Team in Harrison Bay above Alpine (farthest point west)
TOP FROM LEFT: Charlie Zacarias, Cyrus Nukapigak, Rodney Wilson, Arnold Arey, Nick Baggarly, Richard Tukle BOTTOM FROM LEFT: Rod Roddenberry, Douu Pape, Sherman Hon.
(Photo by Rod Roddenberry)

PTV2 RECOVERY

After we returned to Deadhorse, team members Hon, Roddenberry and Wilson flew home and February 8 and 9 were spent meeting with Peak Oil to investigate vehicle recovery options. The remaining team

members were Nick Baggarly and the two Marines, Charlie Zacarias and Doug Pape, and during this period considerable sums of ice cream and pudding were consumed. After some brief meetings, Peak quoted a minimum of $25,000 to extract the vehicle but offered a second, more economical, option that involved flying to Barrow with parts to fix the vehicle and then riding with a Peak rollagon crew that was making their return journey to Prudhoe Bay across sea ice. It was determined that our vehicle was very close to Peak's route, so their convoy would stop and bill for only the hours taken to repair the vehicle and, once repaired, we could follow them out. This option was not selected however because Peak was clear they could not perform any extractions or towing if the vehicle became stuck in a snow drift or if the repair was unsuccessful. So, it was decided that Baggarly and Zacarias would attempt to recover the vehicle with assistance from Arnie's North Slope Cargo which required a new services agreement. An incoming Phase 2 storm with 50 MPH winds predicted was the catalyst for swift preparations. Given the seriousness of the situation, the group decided to take considerable time to plan so as to prevent problems, and this was some of the best teamwork that took place on the expedition. Going out in this manner meant it would not be impossible to take the full complement of expedition gear and spare parts, so the three carefully planned the recovery going over each step several times and making a list of all tools, parts and equipment needed. The threat of an incoming storm meant they had to carry full ECW gear including, minus 40 degree sleeping bags, two types of flare guns, a DeLorme InReach satellite messaging system, Pains Wessex emergency beacon and food and water for several days. Baggarly and Zacarias loaded their guide's trailer with gear and supplies and Pape stayed behind and single-handedly packed vehicles for the return journey.

The recovery plan was as follows: 1. Drive the rental truck and trailer, along with guide's Dodge truck, to Oliktok Point, 2. leave the rental truck behind, 3. put Mattracks on the guides' vehicle and transfer everyone to this vehicle, 4. put into the sea ice and navigate to PTV2's coordinates, 5. replace the broken hub, 6. convert PTV2 to tires, 7. drive the vehicle out. Prior to departure, two geared hubs were removed from PTV1 and the front hubs were chosen since they were least likely to be worn. The hubs are "sided" parts and only a left side was required; however, both sides were taken just in case. The plan called for sea ice ingress at Oliktok Point since this was a route that our permit allowed. The morning of departure, Carlisle delivered the SnowStream to Deadhorse so we were able to retrieve necessary parts and gear. We followed our guides and stopped for lunch at Kuparuk Camp. During lunch our guide suggested we put in further down the road at "the island" which was later discovered to be OOGURUK Island managed by Caelus Energy. We drove the Prudhoe road system to the start of a 4-mile-long ice road to OOOGURUK island and received permission to leave the truck there. Our guides converted their Dodge truck to Mattracks and the five-person team returned to the ice. Dead reckoning navigation was used based on a GPS fix on PTV2's position taken by Sherman Hon, and approximately 40 miles later the snow-packed vehicle came into view. After three days stranded on the ice in temperatures that ranged from -10°F to -30°F, PTV2 started without incident and did not require a jump start. Within 45 minutes all systems were pre-heated and the vehicle was operational which was the best cold-soak test to date. A video taken during the first moments of rendezvous with PTV2 can be viewed here.

After the left-side hub was replaced, and track installed, the right-rear track was removed and the spindle clamp nut was checked for excessive end float. It had none so the track was re-installed. Zacarias suggested changing the recovery plan and driving the vehicle back to Prudhoe Bay on tracks which was agreed. Approximately 40 miles later, PTV2 successfully reached OOGURUK Island and the two said farewell to guides, Arey, Tukle and Nukapigak. They retrieved the support vehicle and departed the island along the four-mile ice road. During this stretch, the solid ice surface was very slippery and the rear of PTV2 was now very noticeably pulling to the left. Although the left-rear hub had been replaced, a rear-end binding issue was still occurring and very-much noticeable. This suggests that the hub failure

was likely caused by binding somewhere else in the driveline--an axle, differential or brake issue perhaps. The vehicle traveled at 35 MPH for approximately ten miles on the Prudhoe road system and then PTV2's right-rear spindle broke. Fortunately, they came equipped with a replacement and it was repaired on the side of the road. Having broken both rear hubs within 50-miles of each other, a rear differential, axle or brake binding theory was now a genuine concern so rather than continue on, they decided to drive PTV2 to the nearest inhabited pad, which was the ConocoPhillips tool shed, and leave it. Later that morning, Carlile retrieved PTV2 and brought it back to Deadhorse. An examination of this issue is critical to the success of future missions. A list of possible causes or contributors are in the failure analysis table below.

PTV2 FAILURE ANALYSIS

PTV2 GEARED HUB FAILURE POSSIBLE CAUSES AND CONTRIBUTORS	**PROBABILITY**
rear end alignment was noticeably out	HIGH
gears and spindle inside geared hub were worn, weak or abused from previous owner	UNKNOWN. Disassemble and inspect damaged hubs
loose or weak clamp nut	UNKNOWN
tow bar induced side loading into vehicle (and tracks)	UNKNOWN
differential problem (binding)	HIGH (PTV2 rear end was noticeably pulling to the left during the 953-mile drive through Alaska which would suggest a binding problem in the rear. The possibility that the brake modulation (locking) feature of the HMMWV differential is incompatible with the electric motor and brake system combination. This should be investigated.
axle problem (binding)	HIGH (PTV2 rear end was noticeably pulling to the left during the 953-mile drive through Alaska which would suggest a binding problem in the rear
brake or emergency brake problem	HIGH, PTV2 rear end was noticeably pulling to the left during the 953-mile drive through Alaska which would suggest a binding problem in the rear. PTV2's emergency brake cable was adjusted frequently during the drive north and may be the cause of binding.
the tow bar exerts considerable tongue weight	UNKNOWN, tow bar design seems problematic
spindle weakening occurred due to high side loads placed into rear tracks by the sled's tow bar during tight turns or u-turns on snow	UNKNOWN, PTV2 made between two and 4 u-turns while sled was attached, tow bar design seems problematic. NOTE: if side loading is found to be the cause we MUST add a warning to vehicle training guide and *Driver* role definition.
PTV2 was overloaded	PTV2s roof rack carried approximately 25 gallons of fuel and a set of four tires. In hindsight the tires should have been placed on PTV1's roof rack or placed beneath the SnowStream on the sled
on acceleration, the tow bar's slip joint bottoms out and sends a shock "thud" (a sudden load) into the rear end of the tow vehicle	UNKNOWN, tow bar design seems problematic

Braving -20° Fahrenheit and 20 MPH winds, Charlie Zacarias replaces a geared hub on PTV2. Component-level repair is necessary rather than attempting a rebuild in-the-field. (Photo by Nick Baggarly)

VEHICLE PERFORMANCE METRICS

Another goal of the expedition was to derive performance metrics such as miles per gallon with tires and with tracks mounted--and with the vehicles pulling their sleds. Measurements were taken while driving on roads, on snow and on ice surfaces that mimic what we will experience in Antarctica. A last-minute decision to omit the fuel bladder sled resulted in inconclusive fuel log reporting while the vehicles were traversing and towing on sea ice. As such, these metrics are not available.

TEST	PTV CONFIG	SURFACE	RESULT
NOTE: PTV Fuel tank holds approximately 50 gallons. Testing occurred with vehicles fully laden			
miles per gallon	tires	roads	9.33 MPG
	tracks	roads	n/a
miles per gallon while towing	tires	roads	n/a
	tracks	snow/ice	n/a
driving range	tires	roads	466 Miles
	tracks	snow/ice	n/a
driving range while towing	tires	roads	n/a
	tracks	snow/ice	n/a
safe driving speeds	tires	roads	50 MPH
	tracks	snow/ice	5-25 MPH
	tracks	roads	30 MPH

FUEL SLED AND REFUELING

We made a last-minute choice to de-scope our objectives and omitted the 750-gallon fuel bladder sled. This was disappointing however, our schedule did not permit the time it would take to set up the bladder sled and train the team. This decision meant that we would have to carry spare fuel in jerry cans so, while in Deadhorse, team members Winberg and Hon were asked to estimate required fuel reserves to carry as Borgie and Pape procured necessary fuel containers. Standard metal jerry cans were not available so plastic 5-gallon fuel containers were purchased. These were stored on the roof rack but, due to the slippery nature of plastic against metal bars, they had to be lashed securely which translated to considerable time to stow full cans and unlash them when taking them from the roof rack to ground level for use. This seemingly trivial task was a miserable experience as dispensing required long periods of outside exposure. If cans are to be carried in the future, the roof rack must have sockets for each can and a means for swift access and stowage. The decision to use cans was last minute and significantly altered our fueling scenario as procedures working with fuel cans had to be worked out in the field. Rather than using the convenient gas-pump handle--which was our primary means of refueling--the plastic cans could not be dispensed easily due to the high position of the vehicle's fuel filler which is approximately five feet from the ground. The vehicles were often refueled with one individual precariously standing on the track of another vehicle that had to be moved beside the vehicle that required fuel--then, a person had to climb into position while a second person prepared the fuel can on the ground for dispensing and carefully handed it up to be dispensed amid limitations of extreme cold, wind and bulky gear. The weight of the can made this difficult. Eventually, a siphon hose was borrowed from our guide which allowed refueling to take place from the roof however this still required two people and dispensing took longer due to the small diameter flow rate of the dispensing tube which resulted in considerable outside exposure. Using cans also took a toll in the form of several pairs of fuel-soiled gloves and at least two people spilled fuel on their clothes. The constant smell of diesel is a considerable irritant and care must be taken to avoid this in the future. Despite our carrying a plastic rain suit for this exact purpose, the suit was not accessible and even it if was, wearing it would have been a hassle. This was something we suspected and the team had been cautioned to avoid spilling fuel on clothing and gloves, however it was unavoidable due to the equipment selected, the challenge of the vehicle's high filler neck and the strong winds. One recommendation is to add refueling training that covers dispensing from fuel cans and to procure better fuel cans and dispensing and lashing accessories. Refueling from cans was not a scenario that we expect to do but it is often something that must be done. For this reason, this scenario should be added to our fuel training and practiced before every expedition with the entire team present.

LOCATION AND ACCESS FOR GEAR AND TOOLS

This expedition made clear something we have always known but still must work on: every single item we bring must have its place. Even simple operations can be extremely difficult in extreme cold environments. For example, a stubborn latch to lower the vehicle's rear stairs can translate to ten minutes of exposure and frustration fiddling with a screwdriver to dislodge it. There is little time to fix small things in the field because the team is anxious to get the vehicles back on the road and make some distance. The end of each day, and beginning of the next, are filled with issues which must be fixed. Therefore, everything must work--REALLY WORK--before setting out. Additionally, every item must have a very fast, and very robust, lashing and unlashing mechanism and the need for this cannot be overstressed. Tools especially must have a designated home and should be divided into multiple tool boxes or bags that are light enough to be carried individually from the vehicle to the work site. If a bag is too heavy for one person to lift, there is a tendency to keep it in the vehicle and make trips back and forth which results in vehicle doors being left open and any heat generated is lost. Team member

Roddenberry discovered the benefits of storing gear bags vertically against the interior wall so cleats with pre-sized straps should be added to the walls for this purpose.

WEATHER AND LOW TEMPERATURES

While on the frozen ocean, temperatures were typically -10°F to -20°F and winds at 10 to 20 mph, with gusts to 30 mph and wind chill often at -40° or below. Prolonged experience in these conditions provided several useful lessons. One of them: Before stopping or parking for long periods or refueling, the direction of the wind should be considered. It would be useful to add a sign to the dashboard that says, "CHECK WIND DIRECTION BEFORE PARKING." The team's reaction to low temperatures also provided valuable information. Extreme low temperature is a variable that plays tricks on your mind and makes even simple operations difficult. Approximately half of the team had previous experiences in temperatures below -40°. The others had experienced temperatures just below zero. Everyone did quite well but the first group clearly knew what to expect and was more mentally prepared. The conditions seemed somewhat shocking to the second group but they would probably do as well as the first group next time. The point of this observation is, 100% of the Antarctica team should possess previous experience working in temperatures below -20°. The team would often point out how the cold affects materials and marvel at items like highly-adhesive "Gorilla" duct tape which lost virtually all of its sticky qualities at -20°F. The cold begins to take a grip on the mechanics of anything that moves. Latches and doors need to be lubricated and a can of de-icer or WD-40 should always be within reach. Touching metal in subzero temperatures was a painful experience as getting lug nuts started on studs could only be done without gloves due to the tight spaces and fine dexterity required. Our guide knew this and replaced all of his lug nuts with 2 inch long versions that stuck out further and could be started with gloves. One oil company worker said his company's safety rules did not permit employees to touch exposed metal without gloves. Before going outdoors, people would take a moment to plan out their activities and share their plans with each other. Often a team member would make suggestions to decrease their exposure time or offer to assist. A previous day's triumph working in the cold did not seem to make the current day's operations any easier, as people were often taken aback by the immediate and extreme effects of the cold. Even zipping up your jacket is hard when it takes five minutes to work through an ice packed zipper. One person said, "it felt like the cold was physically gripping my arms and legs." Another said, "a day in this environment was exhausting." Doug Pape said just one word, "brutal." Breath mist was as thick as cigar smoke. It was difficult to breath especially if the wind was blowing toward you, and it even began to affect your speech. One lesson learned is that expectations must be clearly set that even the simplest things are going to take longer to do. Seat heaters, windshield defrosters, air intake heaters and heat exchangers all worked flawlessly and were all quite necessary. Another thing we learned: if it's not bolted, latched, locked down fast or tightened there was potential for items to loosen or fall off the vehicle. We saw this with the aluminum belly skin of the Airstream which became a sail and ripped through a dozen 3/16" rivets--and with license plate frames and other items. Several North latitude phenomena were observed including, Phase 1 and Phase 2 storms, common ice fog, the aurora borealis and we were even treated to a snow rainbow.

Wind patterns are left in the ice pack that covers the Arctic Ocean north of Prudhoe Bay, Alaska. (Photographer unknown)

EXPEDITION SPARE PARTS, EQUIPMENT LIST, AND INVENTORY

Since the beginning of adventures, explorers have been faced with questions of what to bring on their expeditions and where items will be stored. One day, portable 3D printers capable of fabricating required items from any medium will be an equipment staple but, until that day, it continues to be impossible to bring everything you need. Not having everything means you can't afford to take a lot of risks so a team must be able to improvise. Your vehicle is your umbilical back to civilization so you must always treat it well. If something goes wrong, you must stop and address it. Though inconvenient, it is often best to address the problem immediately and this is a philosophy that has served us well, since a broken machine tends to get worse and break other things. Many do not understand how quickly you can go from making forward progress to a situation where you are reacting to a problem, so knowing when to take risks and when to play it safe is a challenge. Accepting your situation and dealing with it gracefully is also a required skill.

It is understood that, once in Antarctica, the team will have to rely solely on the items they bring. If an item is missing, the only option is to improvise or go without it. The Alaska expedition was instrumental in expanding and honing the Expedition Equipment List--a document that itemizes all vehicles, spare parts, gear, supplies, consumables and equipment that must be taken on any ZERO SOUTH expedition. The ZERO SOUTH Excursion Checklist, created by Brock Winberg, was also consulted as it contains a list of items to pack. These document drove the creation of an Alaska Expedition Inventory which was specific to this mission and quite useful on several occasions. It was developed as part of OPERATION : PACKUP which was our focused effort to gather, organize, classify and document every single item to take on the expedition. For example, when the SnowStream was delayed, we were able to look at the inventory and know what we had and what we did not have. This informed decisions on whether it was possible to drive to Prudhoe Bay and what items we needed to pick up prior to the drive. The delay with the SnowStream caused many resource problems and some anxiety within the team. A common sarcastic request for a needed spare part was, "it's in the Airstream" which meant the needed spare was 2000 miles away. This occurred so often that Doug Pape renamed it, "the SpareStream" and Charlie Zacarias went a step further and commissioned a custom-embroidered hat with the phrase, "it's in the SpareStream." The absence of so many things presented the team with a set of challenges that demonstrated their resilience and ability to adapt to a difficult situation. The inventory also came in handy during PTV2's recovery. Should something else go wrong we needed to be ready to deal with it,

but with only one PTV and a Dodge support vehicle, there was the added complexity that only a subset of tools and spare parts could be on hand. The inventory allowed us to review what we had and make swift determinations for what to bring out to the repair site and what to leave behind.

Team member, Charlie Zacarias commissioned a custom-embroidered hat with ,"It's in the SpareStream." The team demonstrated composure and humor in response to a difficult situation. (Photo by Nick Baggarly, duh)

IN-VEHICLE CAMERAS AND DRONES

Numerous experiments to outfit the vehicles with GO-PRO cameras were conducted by Rod Roddenberry using a variety of locations and mounts. Some of the locations included, on the windshield and side windows, roof racks and even inside the SnowStream sled to observe how the interior was affected while underway This resulted in a number of lessons and recommendations. Frequent battery failures due to cold prompted a suggestion that USB power wires should be run to all designated camera locations. ZERO SOUTH is sponsored by DSLR Pros. Two drones were included in the Alaska test but were not used.

WASTE DISPOSAL

ZERO SOUTH strives to conduct a radical-self-reliance, ZERO impact traverse that leaves behind only tracks in snow. This means that any spill, no matter how small, must be cleaned up and properly disposed of, and no human waste, trash or debris are to be left behind. The team did a good job following this mandate. PTV2's immobilization at GPS position, North 70°, 32.970 minutes by West 151°, 47.286 minutes resulted in approximately one quart of 75/90 synthetic gear oil to be spilled on the surface of the frozen Beaufort Sea. Team member, Rod Roddenberry used a shovel to scoop approximately two cubic feet of oil-contaminated snow into a tall kitchen bag which was hauled back to Deadhorse. The majority of this spill was concentrated in one area with a short ten-yard drip trail leading up to it. All material was collected and left at Carlile Transportation's disposal site. The only other vehicle waste product was hydrocarbon release and, while on the ice, the three vehicles consumed an estimated 110 gallons of diesel fuel. Human waste was stored in wag bags and dispensed down a chute in the SnowStream into a tall kitchen bag. Doug Pape disposed of this material at Carlile's disposal site in Deadhorse.

TUNDRA DAMAGE

The ZERO SOUTH Expedition did not traverse any tundra and thus no tundra damage occurred.

VEHICLE ISSUES REPORTED BY SYSTEM

The vehicle was engineered from the ground up using parts and systems that were proven in other applications to meet or exceed a set of temperature and application criteria as defined by the ZERO SOUTH Vehicle Integration Team. The integration of these components however, created something new which overall worked quite well. This means the thousands of connections, crimps and seemingly-endless fussing worked, or at least the vast majority. Because the extreme environment increases the risk of breakdowns, redundant components were a priority. As such, the vehicles can function with just one electric motor, one drive axle and one battery pack. They can maintain low-voltage power by using the engine's alternators or by using power converted from the high-voltage pack. They can steer using engine-driven, mechanical power steering or using an electric power steering pump. Redundancy also explains why DATW expeditions include at least two vehicles. If needed, the vehicles can conceivably be tethered so one can run from the other vehicle's high-voltage batteries. The ability to tether was on hand, however it was not put to the test.

The following vehicle systems experienced issues which are described in detail in the Vehicle Issues List below: Steering (numerous issues with belts and massive steering wander), Brakes (numerous issues), Drive Line (rear end binding in PTV2), Body (doors, latches, windows and body lift), Front Electric Motor and Inverter (incorrect temp reporting and sporadic incidents of motor not contributing to traction), Battery Precharge Dash Panel (switches and lights); Relay Fuse Box (blown EHPS Pump Relay), Interior/Cab Area (numerous), Interior Cargo Area (numerous), Fuel Tank Connection Tube, Steyr Engine Control Center, Accessories (headlights, tail and brake lights), Tracks (numerous) Snowstream, Snowstream Sled, Tires (pressure fluctuations)

Despite these problems, the majority of vehicle systems exceeded expectations, and it is important to highlight what worked. No problems were experienced with the following systems: Chassis/Suspension, Engine ECU, Engine Intake and Exhaust, Engine Fuel System, Fuel Tanks, Thermal System, Vehicle Control Box, Blue Sea Switch Panel, Generator Electric Motor and Inverter, Generator Mounting and Coupling, Rear Electric Motor and Inverter, Drive Motor Mounting and Coupling), Inverter Mounts, HV Power Distribution Unit, HV Battery Box, HV Battery Box Support Brackets and Bushings, BMS, HV Plug In Charger, Low-Voltage Battery System (hybrid mode consumption averages 75 amps steady state), DC-DC Chargers, Vehicle Computer, Interior lighting, 110 Inverter, Documentation, Custom Tools, Seat Heaters, Air Intake Heaters.

VEHICLE MAINTENANCE, RECORD KEEPING AND ISSUE REPORTING

During the expedition, the three electric motors in each vehicle continually logged data and, upon return to Los Angeles, the vehicle computers were sync'd with Google Docs and logs are available here. Team members Winberg and Zacarias produced a useful Morning and Evening Inspection and Maintenance Checklist and, with help from the team, completed it thoroughly each day. While on the ice, nearly every vehicle problem required two mechanics to perform the repair and one or two additional team members to support the repair running for needed parts, tools or supplies. Future deployments should include an additional, career mechanic with extensive field repair experience in extreme-cold environments and trained to work on the PTV. Pre-departure enhancements like windshield squirters, new wiper blades and the LED light bar worked well and were critical to have in a snowstorm. Good wiper blades are essential and spares must be carried. The team kept a log to record fuel stops along with the location of each stop, fuel quantity taken and distance driven since the last stop. In the future, we should also log all repairs and maintenance no matter how insignificant, along with the location of where they occurred and take images to document any repairs. Logging each repair, or change to the vehicle, would have been valuable information so this has been added to the mechanic and engineer

role definitions. In the back of each logbook, team members were encouraged to write suggestions or issues with the vehicles as they came to mind and many issues and suggestions were captured in the Vehicle Issues List summarized below.

(Photo by Nick Baggarly)

SNOWSTREAM SLED PERFORMANCE

Overall, the SnowStream and its sled did well. This is due in large part to a dedicated group of designers that include, Dave Lovejoy, John Dickerson, Nick Baggarly, PL Questad, Noah Watenmaker, Thao Pham, Brock Winberg, Cole Winberg and Charlie Zacarias.

SLED PERFORMANCE

PTV2 was the prime mover for the sled during the majority of the sea ice drive. Vertical movement of the skis could be observed while underway and they articulated well and kept the SnowStream level despite 1-3 foot snow drifts and uneven surfaces,. The tow bar on the sled uses a pintle ring which was not adequate and added considerable tongue weight to PTV2. This may have been a contributing factor to the broken spindle on PTV2. When the vehicle became immobilized, the sled was towed by our Guide's Dodge truck however, his preference was to use a strap to tow the vehicle rather than the tow bar. This worked well but was only possible because the surfaces were flat and level. The team should consider replacing the tow bar with a lightweight solution that incorporates a universal joint at the receiver. The tow bar's slip joint was broken at the end of the expedition when Carlile attempted to move the sled. It is not advised to have riders in the SnowStream while the vehicle is moving. The sled's storage baskets worked to hold spare parts and gear in plastic bins however the bins were very difficult to access. A custom-fabricated storage bin, with suitable handles and made to fit inside each basket, should be fabricated from thin aluminum or thick, temperature resistant plastic. Each basket should have a strap or heavy-duty bungee cord permanently fastened to one side so bins are quick and easy to remove and stow.

Changing PTV1 to tires for the drive off the ice. Playing it safe yields options to return another day.
(Photo by Rod Roddenberry)

SNOWSTREAM INSULATION AND INTERIOR LIVING SPACE

The insulation performed well and the outfitting was adequate. One Espar heater was enough to keep the SnowStream at 60°F despite temperatures hovering around minus 20°F outside. This was likely enhanced by having six people inside. The door on the SnowStream needs a better seal and latch mechanism as well as a new door stop. Also, anything large and flat acts like a sail in high winds which we learned when the aluminum belly skin was ripped off by high winds. The perimeter of the thin aluminum had leaks that allowed air to get in and eventually separated the material despite dozens of rivets. The bunks were adequate and allowed the majority of the team to get eight hours of sleep during one night. Some repair work needs to occur with the bunks to strengthen them. The toilet worked well and was used by all team members--however, the accordion doors were flimsy and the magnetic latches did not keep the doors closed so the doors should be changed to something more robust or at least better latches. The biodegradable wag bags were not big enough to stretch over the toilet bowl (bucket) and ripped easily especially when cold, so thicker biobags should be sourced. The connection tube in the dispensing chute came off from high winds and the waste bin enclosure door latches require adjustment.

COOKING, SNOW MELTING AND HOT WATER PRODUCTION

The expedition solution to produce water from snow (aka, snow melting) was not ready in time however, three methods to produce hot water were included. 1. two 700 watt electric kettles. 2. A MSR Stove that uses white gas. 3. A butane stove with metal gas canisters. The electric kettles did not work and the MSR stove was included for emergency use only since it is not rated for indoor use. The butane stove was also intended as a backup but became the primary source to produce hot water. A new method for making hot water fueled by either electricity or ethanol should be selected. Doing so will preserve our goal of being a single-fuel-source expedition.

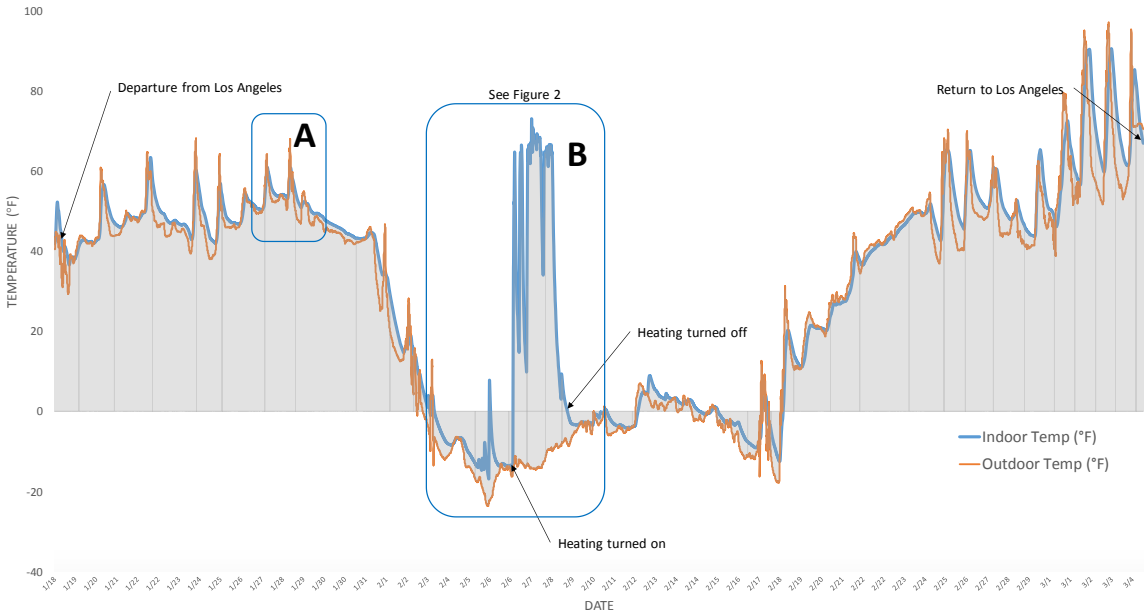
Sherman Hon takes a well-deserved break inside the SnowStream while Doug Pape prepares coffee and hot meals for the team using the expedition backup stove. (Photo by Rod Roddenberry)

ENVIRONMENTAL DATA LOGGERS

Zero-Net Transportation (ZNT) is at the core of ZERO SOUTH's 1,200 mile journey across the Antarctic. While ZNT research is a high valued asset to land vehicles of Antarctica, developing a Zero-Net Mobile

Habitat (ZNMH) is equally critical in environmentally sensitive environments. In tow, our re-engineered Airstream (Snowstream) is equipped with aerogel thermally enhanced walls and environment appropriate heating system that uses bio-kerosene fuel to achieve a sustainable low carbon footprint. The Alaska test included a research objective to characterize the energy performance of the Snowstream and evaluate occupant thermal comfort as a function of the energy required to sustain habitat. Two Onset HOBO (U12-011) data loggers were deployed on the Snowstream with one placed inside and one outside in a weather protected enclosure. Units were placed by Eric Carbonnier of HMC Architects under the supervision of Expedition Field Science Coordinator, Jonathan Knowles. Questions we attempted to answer include, how will the aerogel walls perform in subzero environments? How much energy will it take to sustain human comfort? What strategies will the team adopt to achieve thermal comfort? Methods central to achieving a sustainable habitat require understanding the nature of four environments: the exterior environment, the Snowstream's envelope, the interior environment, and human behavior. The data loggers are mini weather stations that continuously monitor and record envelope vitals using a combination of sensors. At the end of the expedition, the devices were removed and returned for analysis. Both of the 2-channel data loggers worked to catalog over 30,000 data points of temperature, relative humidity, dew point, and a host of other operational variables. The loggers were programmed to start on January 18, 2016, and took readings every 5-minutes until March 5, 2016. The data file is available here. The outdoor temperature and indoor temperature are represented in Figure 1. Spikes in temperature reflect diurnal rhythms - noted with an A on Figure 1 - and can be seen throughout the expedition with exception when the indoor heating system was turned on - noted with a B on Figure 1. As the Polar Traverse Vehicles and Snowstream approached Alaska the ambient temperature gradually decreased as anticipated. Conversely, as the equipment left Alaska the ambient temperature gradually increased.

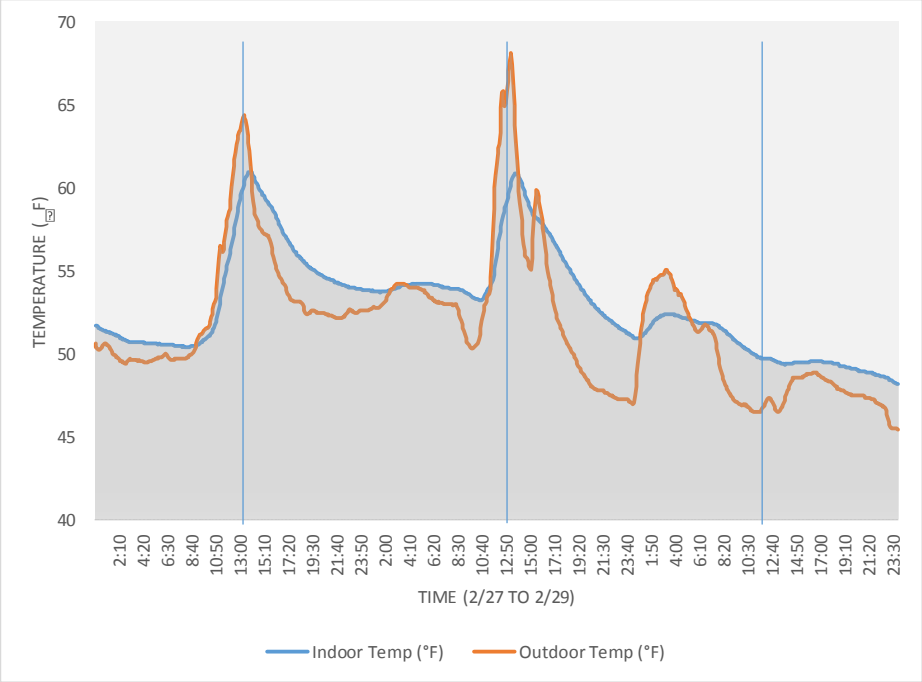
Figure 1: Outdoor & Indoor Temperature



Two areas of interest were magnified to better understand the thermal performance of the Snowstream. Area A (Figure 1) reflects a typical non-operational status of the Snowstream. The indoor temperature swings are generally more moderate than outdoor temperatures. Indoor temperature during peak outdoor temperature remained 2-6°F cooler and 1-3°F warmer in the evening and early

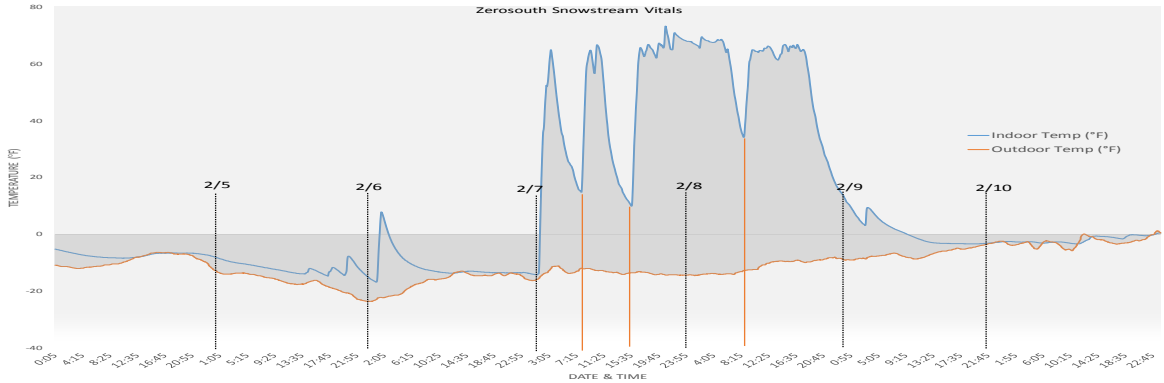
morning hours. These findings are to be expected and may be slightly skewed due to convective forces experienced during transport.

Figure 2: Area A Magnified



Area B in Figure 1 is magnified and illustrated in Figure 3. Area B captures February 5 through the 10 where it appears that an internal heat source was applied to the Snowstream. Based on the readings there was an anomaly around 01:25 (00:25 UTC-8) raising the temperature from -16°F to 7°F and then declining to sub-zero (°F) temperatures shortly thereafter. On February 7th it appears that a heat source was turned on at 01:45 (00:45 UTC-8) with a starting indoor temperature of -10°F and climbed to a maximum temperature of 64°F in less than 2 hours. Indoor temperatures then dropped to 14°F at 08:00 (07:00 UTC-8) when the heat source was reapplied, bringing the indoor temperature to a maximum of 66°F within 2 hours. This trend appears twice on the 7th until the evening when indoor temperatures average approximately 67°F until March 8 at 05:20 (04:20 UTC-8) when heat source was turned off or set to a lower temperature.

Figure 3: Indoor & Outdoor Temperature Enlarged



Based on this effort, the Antarctica expedition should deploy a more robust set of data loggers to capture broader more informative measurements including, kBTU, C02, carbon monoxide, and track the operations of doors and vents and human behavior.

TEAM PERFORMANCE

There is a tendency for these reports to weigh heavily on vehicle performance and avoid talking about team issues: and yet, the behaviors and inner workings of the team are just as important to project success.

The Antarctic mission requires development of a great team and the Alaska project revealed several personnel issues that provide opportunities to build a more-engaged group. Overall, team members responded favorably to their roles and delegated tasks and complied with requests nearly 100% of the time, which was admirable. Several did not take to their role or regarded it as beneath them or with reluctance and a culture absent of this should be fostered and, at times, demanded. This expedition highlighted just how demanding a program ZERO SOUTH is and how much team support and institutional knowledge it requires. More training events and training exercises must occur for many common processes and for several repair processes. Each training event should be provided for the entire traveling team and not just one or two people such as, how to refuel the vehicle or how to drop the battery box. An expedition team size of ten should be reconsidered. For sleeping, the original estimate of six in the SnowStream was a good number but for daily use as a warming hut for breaks, making food and hot beverages, the habitat sled was crowded with more than six people. A team size of eight might be better. The knowledge that expeditions are highly demanding was keenly felt by all team members. The journey was logistically and physically exhausting and full of situational uncertainty. It was worthy of the term "expedition" since expeditions are usually more than you bargain for and can be like roller coasters that you cannot get off so you must resign to do what it takes until the end. The elements and their discomforts caused occasional bouts of reluctance to perform in one's role and this happened with everyone. This is both natural and understandable but we need to find ways to address this and also minimize stress and frustration. Team members became frustrated and appeared disillusioned by frequent vehicle breakdowns and situational problems that were unforeseen even though everyone knew we were there to test the vehicles. Occasionally, this got the better of us when something broke and the problem was being investigated, since this was the period of highest uncertainty. A disproportionate amount of work fell on the same individuals. This was not particularly anyone's fault but due to the structure of the operation and selection of remote team members. Flight and departure schedules became a big stressor for this operation. People had to be in Barrow on specific dates in order to make outbound flights. The Alaska schedule was structured with multiple participation options because the program would not have happened otherwise: however, any future projects should require a commitment from each team member for the full duration and an understanding they will remain with the project from start to finish. In essence, everyone arrives together and leaves together. This will reduce schedule stressors, enable cross training and distribute the workload more evenly. The Antarctica team participation agreement should include two expedition schedules--one ideal and one pessimistic. The Antarctica expedition term should also include a commitment contingency that adds an additional one month extension if deemed necessary by the expedition leader.

How we achieve our mission and goals are as important as the mission itself, and success will be measured by team member growth and satisfaction and high community regard for the project. Gossip can defeat an expedition before it starts and its presence both occurred and had a negative effect. It must be replaced by an agreement among team members to understand the damage it does and invite open communication instead.

Being cold in difficult, uncomfortable and uncertain situations can cause people to forget the plan, or wish to re-negotiate it, and several team members had to be reminded about the goal of the project. They forgot the mission was to test the vehicle and achieve a place (Barrow) in order to mimic our mission in Antarctica. That said, all team members demonstrated true shining moments of heroism. The break down with PTV2 made continuing to Barrow impossible but prior to it, the team did decide to push on for Barrow which was admirable. They also had the courage to voice their opinions in a diplomatic way. Leadership needs to do better at checking in with team members individually to ensure all is well.

A culture of respect is what we wish to build and this comes from shared experiences. The long drive to the top of Alaska served its intended purpose as a means for the team to get to know one another but out on the ice is where it was clear we had actually formed a team. We had fewer people at that point, more challenges, more pressure and fewer resources--yet this was where some of the best teamwork was experienced. There were times when the team was divided but we worked through it and that is what it takes to build a team. Future expeditions should set new participation requirements for team members and introduce a code of behavior and method to enforce it.

WILDLIFE ENCOUNTERS

No close-up wildlife encounters occurred however, the award for most animals seen by a team member goes to Charlie Zacarias who saw two moose, numerous caribou, an arctic fox and a red fox.

PROCESS AND OPERATIONS

We instituted a policy whereby the driver was required to get out and walk completely around the vehicle before setting off. The idea came from talking with oil field workers who are required to do this since it occasionally catches a loose item, or finds a problem or left-behind item. The driver was also responsible for ensuring all items and equipment inside the vehicle and on the roof rack are lashed securely. Most mornings and evenings, a daily, prioritized TO-DO list of tasks was developed by Nick Baggarly and reviewed with the team with assignments delegated. This was not always well received but it worked well to communicate priorities broadly and ensure everyone had the same information. At nearly all times, the team was well focused. The task of communicating a daily, prioritized TO-DO list should be assigned during every field deployment. Limited fuel reserves and the near-term flight departures were two main stressors that required a constant sense of urgency for the team. Future deployments should offer only one participation schedule with all members required to sign on for the duration. Unloading of vehicles and returning the workshop to normal operation should be part of this commitment. A role of First Officer should be created with the primary responsibility to ensure team members are working within their defined roles. This will free up the Expedition Leader to focus on logistics, long-range planning and 3rd party interactions. Field operations are very demanding so authority should be delegated to this co-manager to help ensure the team is getting what they need (parts, proper training, gear, food, sleep, information, etc).

EXPEDITION PHASE 4 : RETURN SHIPPING AND WRAP UP

On February 14, all vehicles were loaded in Deadhorse onto two trailers by Carlile Transportation for return to Anchorage. On February 20, the vehicles were loaded in Anchorage aboard Tote Maritime *North Star* which departed February 21 on voyage 16024 and arrived in Tacoma on February 24.

On February 28, the vehicles arrived at the Port of Tacoma. The following day, they were transferred to Carlile Transportation's yard in Tacoma and lashed to the same 48 ft step deck trailer that took them northbound (Northwest Salvage and Recovery). The vehicles traveled by road from Tacoma to Los

Angeles and arrived two days later and were unloaded on March 2. Coordination to unload the PTVs at the workshop was performed by Nick Baggarly, Mike Sabbarese, Charlie Zacarias and Pat Young.

MEDIA EXPOSURE

While in Anchorage, a reporter from Alaska Dispatch News interviewed the team and wrote a story which can be found here.

SUMMARY OF LESSONS LEARNED

There were many vehicle-related lessons. For example, we must not overestimate the capabilities of the vehicle's drive line. It is not as strong as we thought and must be up-rated and strengthened for Antarctica. Also, things can freeze up and become inoperative if not designed, installed, tested or used properly. The vehicles need to undergo a comprehensive insulation process like we did with the Airstream. They were too cold. Occupants should be able to remove their ECW gear while inside and a third heater should be added that runs off the engine or a way must be found to trigger the Espar heaters into high output when immediate heat is needed. We obtained real-world data that will permit a final calibration of the vehicle thermal system, and we obtained real-world experiences and lessons related to extreme-low temperature to better prepare for the upcoming mission across Antarctica. We need to outfit the vehicles so items and tools are quickly accessible.

Sometimes you just have to hit the road and start improvising or risk becoming one of those expeditions that never gets underway. The downside is, this expedition, from a technical perspective, was somewhat rushed and this opinion was shared amongst the team members to one extent or another. The need for cold winter temperatures and team member schedules were the main drivers in the timing of the expedition and the project needed to have this push to move things forward. The team did not put much emphasis on the business rationales that drove some of the decisions and instead focused strictly on technical and situational merits. They had been insulated from the business side of putting on an expedition however these decisions and relationships should be conveyed so they can appreciate there are other dimensions that must be factored in decisions.

The most enlightening lessons call for a newfound focus on the human aspects of expeditions. We focused so much on preparing the vehicles thoroughly but we underestimated the human toll this project would take. In extreme situations, the need for cooperation and resilience is paramount, so we should have extended the same preparation efforts to the team. Of course there will always be liabilities in newness but the following course corrections are being applied.

1. MORE AND BETTER PLANNING: We need to conduct more in-depth and careful planning so that we can more easily tackle real-time expedition challenges as they arise. The meticulous logistical planning that was done prior to PTV2's recovery should be employed for all operations. Ideas that came up on the traverse, such as vertical gear storage and directional parking, should be formalized into daily procedures. We need to create more detailed equipment checklists, maintenance guides and integrate them within team roles and training. Build-out of the Antarctica timeline should incorporate allowances for potential schedule delays, such as that which occurred with the SnowStream our first week. We also need to create a formal outline of action steps to take when unforeseen situations occur and the entire team should review, refine and agree to it beforehand. This way problems can be investigated and discussed according to a set of decisions that take some of the mystery out of uncertainty and the team can feel confident in the way problems are being handled. We say this with the full understanding that all plans are subject to reality and the thing that goes wrong is usually something you did not plan for. It was an important lesson that sometimes challenges on the ground, such as the breakdown of PTV2, can

necessitate a change in the project scope and an adjustment on the fly. But more and better preparation on the front-end will help us address unknown scenarios when they inevitably occur. We also need to reexamine and perhaps adjust the number of people that can reasonably co-exist in such extreme, close-packed quarters. Lastly, it was an important lesson to learn that sometimes you can't achieve exactly what you initially set out to do, as seen when PTV2 broke down. We adapted to that challenge and still came away having achieved our stated objective to test the vehicles in conditions that are not available to us in California.

2. MORE AND BETTER TRAINING: More In-depth training is critical. We need to hold pre-expedition technical training events so it's not just one or two people who can do things but all team members can do it. We have plans to expand driver training and refueling training that covers dispensing and lashing. Prior to launch, we'll spend more time setting expectations and conducting gear "dress rehearsals."

3. UTILIZE EXISTING RESOURCES: (aka, don't reinvent the wheel.) It was humbling to be reminded just how important local knowledge can be and we must never forget that we do not possess all the answers. We should trust the locals and go out of our way to engage those with experience or expertise. Prior to the drive to Prudhoe Bay, Todd Borgie and Sherman Hon received many tips and warnings from Northstar's George Nelson who had made the drive dozens of times. We relied upon local knowledge for weather reports as well as our technology to decide the best time to launch the journey's third leg. While stopped in Kuparuk, reliance on the mechanical expertise of workers at ConocoPhillips and Carlile helped immensely in preparing the vehicles for travel. While on the sea ice, our local guide used his longtime understanding of sea ice patterns to create the safest route and strategy for the crossing. We will apply this to Antarctica by reaching out to various contacts at the stations we encounter for weather, route, mechanical, supply chain and parts support. Establishing and maintaining these contacts will be integrated into team roles so all can share in information gathering.

4. THE IMPORTANCE OF TEAM MEMBER SELECTION: There's a resilient spirit needed to address challenges as they come up with a positive attitude. Living in confined quarters in extreme, unrelenting close-contact makes this difficult and not for the faint of heart. Historically we have always looked for expertise when selecting team members--those who deliver solutions that work--but we need to ensure that the team that surrounds this project is the right fit. As we select people to join the team, we must find the means to bring them all together to see how all the personalities work with each other, far prior to an actual expedition so any member who is significantly out of sync with the others can be replaced. One challenge however, due to the exciting nature of our programs, is that many people will claim they are capable of an expedition when, in fact, we learn in the field they cannot hack it. We need to realize there will be challenges finding the right people and address those challenges with clear-cut and practical expectation setting, deeper front-end training and more selective vetting of team members. The team must be qualified and willing and we should make sure everyone is on the same page and agrees ahead of time to what they are committing to. We are good at recruiting based on expertise but we need engaged and dedicated self starters who are good organizers of work and people. We have already compiled a list of the personal and collaborative qualities necessary for future team members to embody.

5. STAY CONNECTED WITH THE TEAM AND RELY ON THEM: It is not enough to simply outfit a team with a good plan and good gear. We need to listen carefully to what they are saying and ask frequently how they are feeling. Expeditions cannot be done by one person and we must not drive people too hard while in the field. The only way to get through it is together. ZERO SOUTH has a great team that can be relied upon. To achieve a spirit of cooperation must be a guiding principal.

PROJECT NEXT STEPS : SOUTH POLE READINESS

South Pole Readiness is the next phase for ZERO SOUTH. It will take three months at a cost of $100,000 to re-stage the project for Antarctica and incorporate lessons from Alaska and many of the vehicle fixes and enhancements described in this report. The final steps for **South Pole Readiness** are to build a new Antarctica Expedition team and raise the final *Project Completion Fund* which is the final round of production capital required to travel to Antarctica. ZERO SOUTH is at a critical phase in its lifecycle. Compelling reasons to begin this phase immediately are to capitalize on the Alaska experience while it is fresh, preserve institutional knowledge and maintain team interest. The ZERO SOUTH vehicle team has been at this project going on eight years. It is a testament to the vision and goals of the project that we have been able to hold the interest of a group who represent the most skilled and talented in their mechanical and engineering fields--but it cannot be assumed they will maintain their interest forever. These men and women are "volunteer engineers"--two words rarely seen in the same sentence. If they do not have what they need in terms of parts and resources they will not show up, so we must ensure we can enable them prior to launching this phase. The most compelling reasons for action now are to give us a window for Antarctica this year and the need to mobilize public support for climate science initiatives is critical now.

IN MEMORIAM

During the Alaska Expedition, ashes belonging to Jay Fiondella and Ralph B. White--two esteemed and decorated explorers--were distributed. Jay Fiondella, owner of Chez Jay Restaurant, helped ZERO SOUTH get started in a small office in Santa Monica, and Ralph B. White, world-renown cinematographer supplied story and production guidance and came up with the project title, "ZERO SOUTH." The location selected, Oliktok Point, is approximately 40 miles west of Prudhoe Bay near the Colville River Delta. Disbursement was performed by Nick Baggarly on February 9, 2016 at 12:00AM PST.

END NOTES

POLAR TRAVERSE VEHICLE - ISSUES LIST

-Post excursion vehicle inspection. Full inspection of vehicle and all systems. (N. Baggarly)
-Clean vehicles thoroughly post expedition. Detail interior, exterior and frame. (N. Baggarly)

HIGH-VOLTAGE BATTERIES AND ELECTRIC MOTORS

-Transfluid couplers now have 1200 miles on them which is very good. Recommend that generator on both vehicles should be removed and couplers examined. (N. Baggarly)
-synch vehicle computers with Google Docs and ensure all motor logs are uploaded to Google Docs UQM Logs directory so team can begin analysis. NOTE: Log uploads are complete. A request has been sent to UQM for log viewer application. (N. Baggarly)
-PTV1 front motor stator temp reported incorrectly. This will require UQM's expertise to suggest course of action after they have reviewed the logs.
-PTV1 sporadic incidents of one of the motors (possibly the rear) not contributing to traction
-Post excursion battery box inspection. Pull battery boxes and inspect internally. Inspect mounts, all wire connectors and bulkhead connections. (N. Baggarly)
-PTV2's battery pack cell voltages look good. On PTV1, one of the packs has mostly cells that are all around 3.82 but there are two cells that are 3.66 and 3.75 while one close to them is 3.9.
-Both battery packs should go through the health cycle test that Sherman and Brock developed in 2014. (N. Baggarly)
-Brock to write up battery box warm up procedure and vehicle startup procedure from a cold soak. Describe steps taken and amount of time to expect. (B. Winberg)
-After a night in a warm workshop with the vehicle completely off (no hydronics running) PTV2's battery temperatures were greater than PTV1's which suggests that PTV2's battery box may be less insulated than PTV1's. NOTE: after a day of driving in cold temperatures, PTV2's battery temperatures were consistently higher than PTV1. This needs to be investigated (B. Winberg)

POWER STEERING

-exchange defective EHPS pump (N. Baggarly)
-Revamp power steering system. Brock suggests removing the mechanical pump and replacing it with a larger electric pump. Pat suggests trying stock pumps. Charlie suggests using only 4-rib belts. PTV2's PS belts lasted much longer than PTV1's so PTV1's pump may also need to be shimmed. (N. Baggarly, P. Young, C. Zacarias, B. Winberg). Charlie suggested having separate brake and steering pumps that have their own separate reservoirs.
-PTV1 replace EHPS relay in fuse box and restore trailer harness switch to power the harness (not the PS pump). This switch was repurposed during a field repair when the EHPS pump relay shorted out (B. Winberg)
-Tons of steering slop and wander on PTV2. PTV1 has a lot of play too. This may be coming from the steering shaft u-joints which seem quite sloppy. Find the cause and fix. (N. Baggarly)

GEARED HUB FAILURE

-PTV2 investigate rear end binding problem (N. Baggarly)
-PTV2 rear end pulls to the left. Find out why. (N. Baggarly)
-Rebuild all geared hubs (N. Baggarly)
-Replace all wheel studs with new (N. Baggarly)
-Spindle studs, geared hub rebuild parts and full replacements on spares and parts to order lists (N. Baggarly)
-Replace all lug nuts with new ones that are longer. Snow would fill around nuts and freeze making removal difficult. Snow had to be chipped away around the lug nuts which was time consuming. It was also time consuming trying to get the stock log nuts (which are short) started since this could not be done with gloves on. For these reason, our guides used a longer lug nut that protruded approximately 1/2 inch out of the track's lug nut hole.
-add to spare parts list: spare complete geared hubs. Spare geared hub rebuild parts (spindles, bearings, gears, seals, clamp nuts, spindle studs and axles). (added to spares list, N. Baggarly)
-Investigate heavy-duty spindles (billet?). M. Sabbarese is already checking into this. (N. Baggarly)
-Call Mattracks and confirm (unequivocally) that H1s are running these tracks. Make calls to customers who are using these tracks and inquire whether there have had similar issues. (N. Baggarly)
-PTV1 rear tracks are (very noticeably) pointed outward. What gives? Very strange. Possible alignment problem. (N. Baggarly)
-PTV2 vehicle alignment (actually, check alignment on both vehicles) (N. Baggarly)
-Check/tighten all axle bolts (N. Baggarly)
-differentials need breather tubes. The diffs leak gear oil through the breather and gear oil drips down the caliper, dangerously close to brake pads. (N. Baggarly)

TRACKS

-perform full track inspection.
-check each track for cuts and tears in the rubber cleats (there are several). Check each rubber track and assess whether any needs replacement.
-Tracks have missing parts. One set of bogie wheels is missing a cap that covers a pivot area. Replace and check other tracks.
-Replace PTV2 LR track bogie wheel (scratched). Check track for other damage. (N. Baggarly)
-Several over limit arms do not have their steel sleeves. Add ten sleeves to the spare parts list.
-The over limit arm bolts ripped out of the socket where the arm attaches to the track. This could be an indication of over exertion from side loading.
-The team should devise a way of towing a vehicle with a broken corner. A 2 foot square piece of railroad tie strapped beneath the lower control arm of the chassis, resting on a recover ski would do it.
-We were careful to switch to tracks safely but we definitely need a new jack system. After our San Francisco test, Brock suggested we devise something that raises the entire axle to the correct height for tracks or tires to reduce the switching time and increase safety. It's time to put some thought into this idea. (N. Baggarly)

LIGHTS

-replace headlights with 7" round Hella lamps with brighter bulbs. Check blue light on dash is hooked up correctly to illuminate when high beams are on. (N. Baggarly)
-headlamp connections near hydronic heaters need to be changed so they don't protrude toward heater's combustion chamber and the headlight offset shims that were added need to be removed. (N. Baggarly)
-clean up LED light wire harness to finalize the installation. Outside wires may require loom and fasteners. (N. Baggarly)
-add reverse (backup) lights (R. Wilson)
-rear license plate mount and wiring on PTV2 need to be fixed. (N. Baggarly)
-Install 3rd brake light on vehicles. (N. Baggarly)

BRAKES

-PTV1 and PTV2: check emergency brakes. PTV2's e-brake required constant adjustment and is definitely not working correctly. (N. Baggarly)
-add 2nd emergency brake and lever. Lever should be located in cab if possible. (N. Baggarly)
-add a proportioning valve to brake system to isolate front and rear circuits. (N. Baggarly)
-change tail lights and brake lights to much brighter bulbs. They are barely visible at night in bad weather. (N. Baggarly)
-brake light switch re-calibration (C. Zacarias)
-Several of the brake caliper bolts were replaced with the correct length. Do we need to replace any others or did we get them all?

COOLING SYSTEM

-In PTV2, we noticed large temp fluctuations between when pressure was lost. Within a minute, temps would fluctuate between 140F and 210F. Pressure test the cooling system. Also, review Steyr cooling system PDF and check PTV2 engine block for coolant leak. NOTE: a cooling system pressure test kit has been added to expedition equipment list (N. Baggarly)
-change all of the small brass cooling system breather fittings. They break easily. (B. Winberg, R. Wilson) Take this opportunity to go to a larger diameter hose. If possible, all hose should be replaced with clear hose that is capable of carrying 200+ degree coolant. (N. Baggarly)
-add a view window to coolant tanks. (B. Winberg)
-It was observed on PTV2 that the hot tank was more than 3 gallons low on coolant (there was an undetected leak that was slowly draining off fluid) however there was no way to tell by visual inspection of the tank fluid level. The tank was low so one gallon was added to get it to the full line (within 1 inch of the cap) but the cooling system was still 2 gallons down. It takes quite a while for air to evacuate the system. (N. Baggarly)

INSULATION (THERMAL)

-PTVs require a very serious effort to insulate the cab and cargo areas--a focused effort like we did with the SnowStream (R. Roddenberry, N. Baggarly)
-Add 1" or 2" heat lines to passenger and driver footwells. Add 1" or 2" heat lines underneath rear benches capped with holes every 6" (R. Roddenberry)
-Seal holes and gaps in cab and cargo area to improve heat retention. Ex: 2" hole in seat under inverter (PTV1) (R. Roddenberry)
-heat from under the benches at back of PTVs and/or articulation fans ---> heat gradient issues. (R. Roddenberry)
-back doors do not seal well. There are visible air gaps in the back doors. (R. Wilson)
-side panels flaps to house and starting batteries do not seal well. There are air gaps in the corners. There are air gaps through the piano hinges. (R. Wilson, N. Baggarly)
-the Espars did not function as expected. Sometimes they would output heat at a high rate and others they wouldn't give out much. Dialing up the thermostat to 80 degrees didn't seem to make a difference as they seemed to come on and off for no predictable reason. We should have a call with Espar to properly understand their behavior and ask if there is a hack that will force them into high gear when we want heat now. Put together questions for Espar and request a meeting. (R. Wilson, N. Baggarly)
-The Espar thermostat controller in the cargo area should be relocated higher toward the ceiling of the vehicle. It interferes with gear that has to slide in behind the seat. (R. Wilson)
-First overnight in the PTV1. 4AM, rear heater quit working and displayed "Flame Out" and would not restart. Used front heater. (B. Winberg)
-Espar exhaust fumes detected in rear heater. It may have just been the exhaust burning against the white heat sock insulation. (R. Wilson)
-The hydronic valves levers inside the cab need to be labeled.
-Both the hot and cold tank should have gauges in the cab.

CAB AREA

- Side steps to get into the cab with boots are very necessary.
-cover up the sides of the Blue Sea panels to prevent damage or accidental electric shock (R. Wilson)
-wiper switch needs to be located on turn signal indicator. (N. Baggarly)
-adjust wiper blade travel on both vehicles. The arms need to swing a little more to the right so check if adjustment is possible. It could be the arm is one notch off but check if there's a way to increase (widen) the arm's travel so the entire windshield is cleaned from edge to edge. (N. Baggarly)
-Always carry spare wiper blades. Good wiper blades are critical. (N. Baggarly)
-K&N air cleaner must be relocated so passenger can see better. (N. Baggarly)

-need accurate fuel gauges (R. Wilson)
-Vehicles need a dashboard redesign that displays all needed information. We need temp displays for the hot and cold tanks. (N. Baggarly) Ambient temp sensor (B. Winberg)
-Install GO PRO mounts throughout vehicle the interior cab and cargo area as well as exterior mounts and run USB power run to each one. Power connectors should all go live using the VEHICLE CAMERAS switch on the blue sea panel. Consult with R. Roddenberry for mount locations. If possible, configure go-pros to auto-record on power on. (R. Roddenberry, N. Baggarly)
-Red HV enable switch was bumped off in the night which led to slamming the contactors. This panel needs a cover. (B. Winberg)
-Add a keyboard tray that slides out from beneath the cab monitor. The tray can mount to the monitor swing arm. (R. Wilson)
-tie down points in floor and sides of cargo area should be reviewed for placement. New points added for strapping down cargo. (R. Wilson)
-Dedicated coffee thermoses in PTVs. Extinguisher mount to double cab doors or ceiling. (R. Roddenberry)
-vehicles need cup holders for driver, passenger and three in the cargo area. It is too difficult to drink out of the hydroflasks while driving. They store hot fluid very well and they are easy to pour so they should be kept but we should provide all team members with an insulated travel mug like the one Doug had because you could take sips out of it easy enough while driving. There should be ten holders per vehicle in total for hydroflasks and travel mugs (N. Baggarly)
-Move the GPS closer to the window and Blue Sea panel. (R. Wilson)
-Add a radio microphone hang up latch to the other side of the Steyr control center mount (R. Wilson)
-Websearch why the Icom radios experience occasional intermittent failures that cause all channel buttons to flash. Consider asking the folks at Ham Radio Outlet in Culver City.
-Sign on the dash that says, "CHECK WIND DIRECTION IN HIGH WINDS BEFORE PARKING TO REFUEL OR FOR LONG PERIODS."

CARGO AREA

-Install windows in back of PTVs (rear door and sides) (R. Roddenberry)
-Fix rear stairs on both vehicles. Latches need to be bent back into position and lubricated. Fabricate new, robust release handles. (N. Baggarly)
-Add cleats and appropriately sized straps for storing gear bags vertically against interior walls (R. Roddenberry)
-The cargo area deck has sharp edges that can cut people (R. Wilson)
-The 15" monitor in the cargo area flickers (which vehicle??) (R. Wilson)
-Review sleeping arrangement in vehicle cargo area such that there be less interference from equipment (R. Wilson)
-There is a fuel smell (leak?) in the cargo area around the filler neck. (R. Wilson). Goo up fuel filler area so fuel does not leak down filler neck into the vehicle's battery compartment (N. Baggarly)
-On PTV2, fuel was observed seeping out of the fuel vent/breather that sticks out of the left side of the vehicle. There is a distinct fuel smell inside the vehicle when the tank is full. Possible clogged breather? (N. Baggarly)
-Post signs in cab and cargo area " OPEN FOOD OR BEVERAGE CONTAINERS ARE NOT PERMITTED. VEHICLES MUST BE CLEANED EACH DAY OR AFTER USE." (N. Baggarly)
-Left side wall of cargo area needs a plaque that says, "ROD'S OFFICE" (N. Baggarly)

OTHER

-Ever since PTV2 returned to LA, upon engine startup the oil light starts flashing, the accelerator buttons do not work and the exhaust gauge goes haywire. Something might be blocking the intake. Check for foul play during shipping such as material placed down the exhaust pipe. The Steyr Control center error screen reports 18:HiEXT_Air charge temp.sensor
-PTV1 front diff may be busted. In order to get PTV1 off the truck, Mike S delivered one 10K hub for the left-front as a temporary measure to install so the vehicle could be moved. This axle had to be removed but the instructions were to remove both axles however only one was removed. On 4/1/2016, the vehicle was driven (not knowing the left front axle was still installed) and a loud bang and spark was seen up front. The front differential needs to be removed and checked.
-PTV1 replace Steyr Control Center panel (B. Winberg)
-body mount bolts are loose (N. Baggarly)
-Replace energy Suspension body bushings (B. Winberg)
-At fuel stations, the pump shuts off before the tank is full because it takes time for the two tanks to equalize. This made it difficult to know how much fuel we were getting. Inexperienced technicians would think it was full when it wasn't even close to full and there were times we would set off thinking we were full when we were not which affected our logs. We should consider increasing tank-to-tank hose diameter to 2"
-PTV2 doors do not lock and do not have keys
-PTV1 windows do not roll up properly, especially right side.

-engine bay needs a bright LED light mounted on underside of hood or beneath light bar (R. Wilson)
-hood needs limit straps. It's a freaking sail in high winds and got away from us a few times (R. Wilson)
-Hood needs stabilization enhancements (B. Winberg)
-fabricate radiator muffs and a place/way to store them under the hood. (N. Baggarly)
-Do not use electric impact gun. Use of electric gun may have compromised studs so all should be replaced. (N. Baggarly)
-Fluid container assortment (buckets and drain pans). Capacity should be enough to hold a full drain of coolant. Another should hold a full drain of engine oil. One for PS fluid and two or three for smaller jobs. (added to Expedition Equipment List, N. Baggarly)
-Add grip tape on ladders (B. Winberg)
-A test should be devised to measure exact tank capacity (estimate is 50 gallons)
-Add a GD task for each training event

SNOWSTREAM - ISSUES LIST

-Replace windows with double pane
-sled bins need to be made custom for each basket and numbered on top, bottom and all sides. Numbering system worked well. The should be made of aluminum or tough plastic that won't break in the cold. Each bin should have a pre-sized strap cut to length or heavy-duty bungee to make removal and stowing fast and easy.
-rear window latches pop open while underway -belly skin tore away due to wind -new "freezer-style" door latch
-the latch that holds the door in the open position needs to be redesigned.
-Espar fuel tanks should be replaced with one single tank that is easy to fill. The manifold leaks and does not use fuel from the middle tank--likely a clog of some kind.
-trim out the perimeter around entry door. The interior wall panels are sharp and someone could cut their hand on them.
-redesign tow bar. It puts too much tongue weight on the rear hitch. It needs a universal. It could be towed with strap -invited Dave Lovejoy to shop and let him know how it did.
-Toilet: consider changing the accordion doors to something more robust.
-Toilet: The wag bags were not big enough to stretch over the bucket.
-Toilet: The wag bags ripped easily especially when cold. Thicker biobags are needed.
-Toilet: The connection tube in the dispensing chute came off from high winds.
-design SnowStream sled roof rack with ladders. Should collapse for transit and stow beneath sled
-repaint the sled blue, paint sled baskets, paint or powder coat the stairs orange, stair rail handle orange
-polish SnowStream (Carlile used tarps which rubbed and left many dark scuff marks)
-door latch does not open. Consider replacing with a freezer door latch.
-check and secure bunk frames. One in the rear is loose.
-fasten belly skin. The Alaska winds ripped it off so use more rivets than you think necessary. Consider adding reinforcement strips around perimeter
-complete optimal snow-melting solution
-figure out a new hot-water boiler using electricity or ethanol. A Primus ethanol stove may be the best solution.