United States Antarctic Program

Polar Technology Conference
Traversing in the Antarctic

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Antarctic Support Contract

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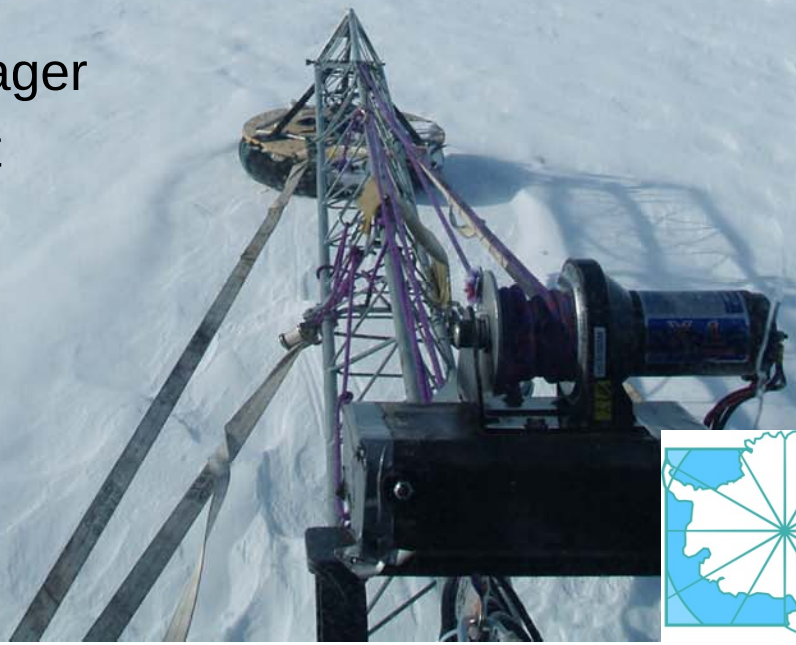


Traverse Mission

- Basic mission is offsetting LC-130 flights to South Pole through delivery of fuel and cargo
  - Offset flights can be used to support Science in other areas of the continent, or more importantly some of these saved flights may not be used at all, which will help to extend the life of LC-130 airframes and save fuel
- South Pole requires ~550,000 gallons of fuel delivered per year; represents ~148 LC-130 missions
- ~30 flights offset per year with one traverse platform
- 2nd traverse platform doubles the annual expected offsets to 60+
- Lead-follow autonomous tractor technology should increase offsets to >90 (2 autonomous-assisted round trips + 1 “standard” traverse)
- Near-term fuel delivery requirement via LC-130s will be ~40% of pre-traverse levels (220,000 to 250,000 gallons = 59 to 67 flights)

- Delivered fuel increases with subsequent traverses because a packed trail provides either reduced fuel consumption or increased hauling capability

Baskin, B., (2008).

Thur, P., (2008).

Traverse season & team composition

- Oct. 25 to Feb. 10 - Deep-field traverse season ~110 days
- Early limit is fairly rigid due to:
  - On-continent fixed-wing Medevac requirement
  - Early season extreme temperatures on the Polar Plateau (<-40°F until mid Nov.)
- Late limit is more flexible because:
  - Fixed-wing Medevac capabilities are generally on-continent until ~Feb. 18
  - Traverse is far from the Polar Plateau by the time late season extreme temps appear
  - Winterization activities (~2 weeks) can be accomplished by the winter-over crew

- First traverse- 10 crew
  - 1 x Field supervisor
  - 1 x Mountaineer
  - 1 x Shop/maintenance foreman
  - 3 x Heavy equipment mechanic
  - 4 x Heavy equipment operator

- Second traverse- 8 crew
  - 1 x Field supervisor
  - 1 x Shop/maintenance foreman
  - 3 x Heavy equipment mechanic
  - 3 x Heavy equipment operator
- GPR vehicle operation is not required since the first traverse has already covered the trail. The traverse drags a GPR vehicle and has the skills if needed.

Operational norms

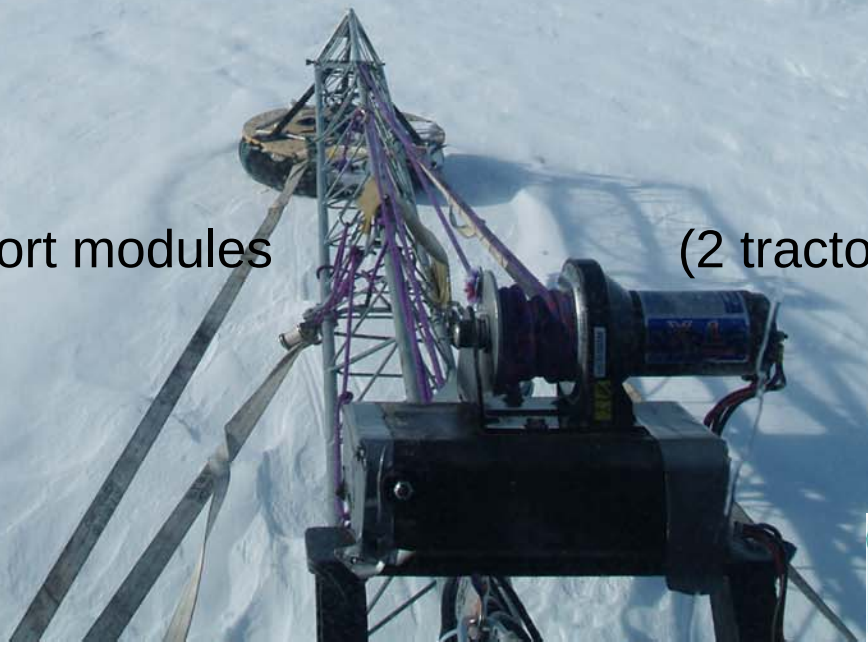
- Goal has been two round trips with one traverse; difficult with current operations
- Planned round trip traverse is ~58 days
  - 30 days Southbound
  - 7 days turn-around activities at South Pole
  - 21 days Northbound
- SPoT1 in ’12 – ’13 = 57 days (31, 7, 19)
- SPoT2 in ’12 – ’13 = 55 days (29, 7, 19)
- Turn-around maintenance between traverses could be up to 2 weeks (9 vehicles + 2 generators + 1 freezer unit per traverse)

- Traverse w/GPR travels at 7 mph maximum
- Heavily loaded traverse w/o GPR travels ~8 – 10 mph
- 10 mph is maximum even for lighter Northbound traverses to minimize wear-and-tear on sleds, equipment, and personnel

Fleet Composition

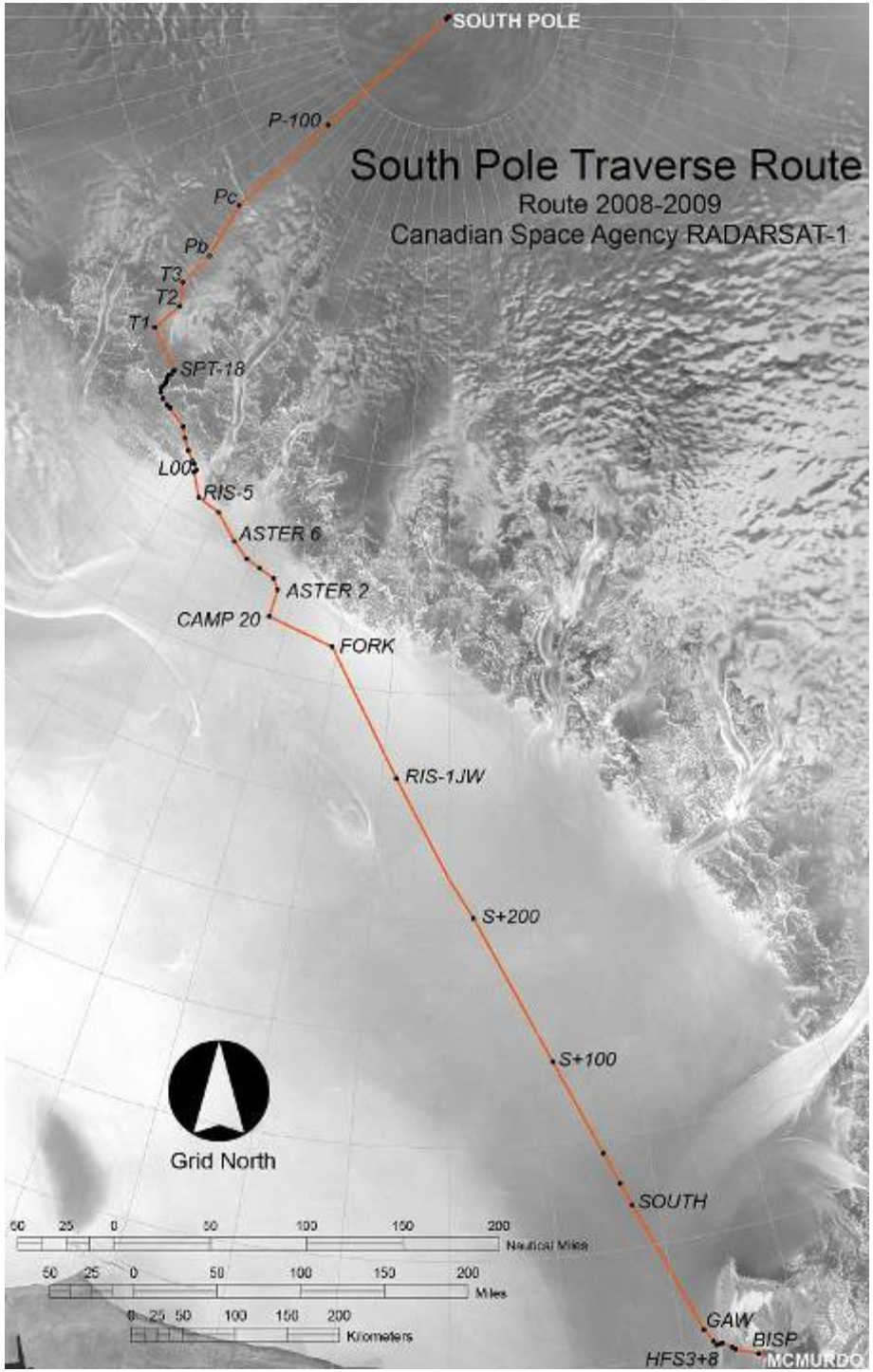
- Each traverse platform has 4 Caterpillar and 4 Case agricultural tractors, 1 snow-grooming type vehicle used for crevasse detection using GPR, and 2 generators
- Fuel usage varies, but general planning estimates are ~28 gallons per mile (gpm)

- 1st traverse platform support modules (2 tractors req'd):
  - Kitchen/berthing module
  - Power/ablution module
  - Freezer unit
  - Tool shed
- 2nd traverse platform support modules (2 tractors re'd):
  - Berthing module
  - Kitchen/ablution module
  - Power/freezer module
  - Tool shed



Fleet Composition, continued

- Case tractors – *3.46 gpm heavily loaded / 2.26 gpm lightly loaded*
  - ~25,000 to ~29,000 lbs drawbar pull
  - Pros- greater drawbar pull, 4 tracks pulling means greater power in turns/fewer immobilizations, lower tractor base price
  - Cons- lengthy end-of-day cleaning process, higher operating costs
- Caterpillar tractors- *2.95 gpm heavily loaded / 1.94 gpm lightly loaded*
  - ~25,000 lb
  - Pros- virtually no end-of-day cleaning, lower operating costs
  - Cons- higher base tractor price
- Pisten Bully 100- *~1 gpm*
- Prinoth BR350- *~1 gpm*
- Modifications include Arctic seals and fluids, plug-in heaters, stand-alone heaters (Espar), upgraded compartment enclosures, double-pane windows, and bulldozer blade, crane, and winch attachments
- Generators, 2 per traverse- not running while moving, each traverse runs one generator about 13 hours/day, season average is *~1 gpm*



1,030 miles

27- McMurdo Ice Shelf

621- Ross Ice Shelf

88- Leverett Glacier

296- Polar Plateau

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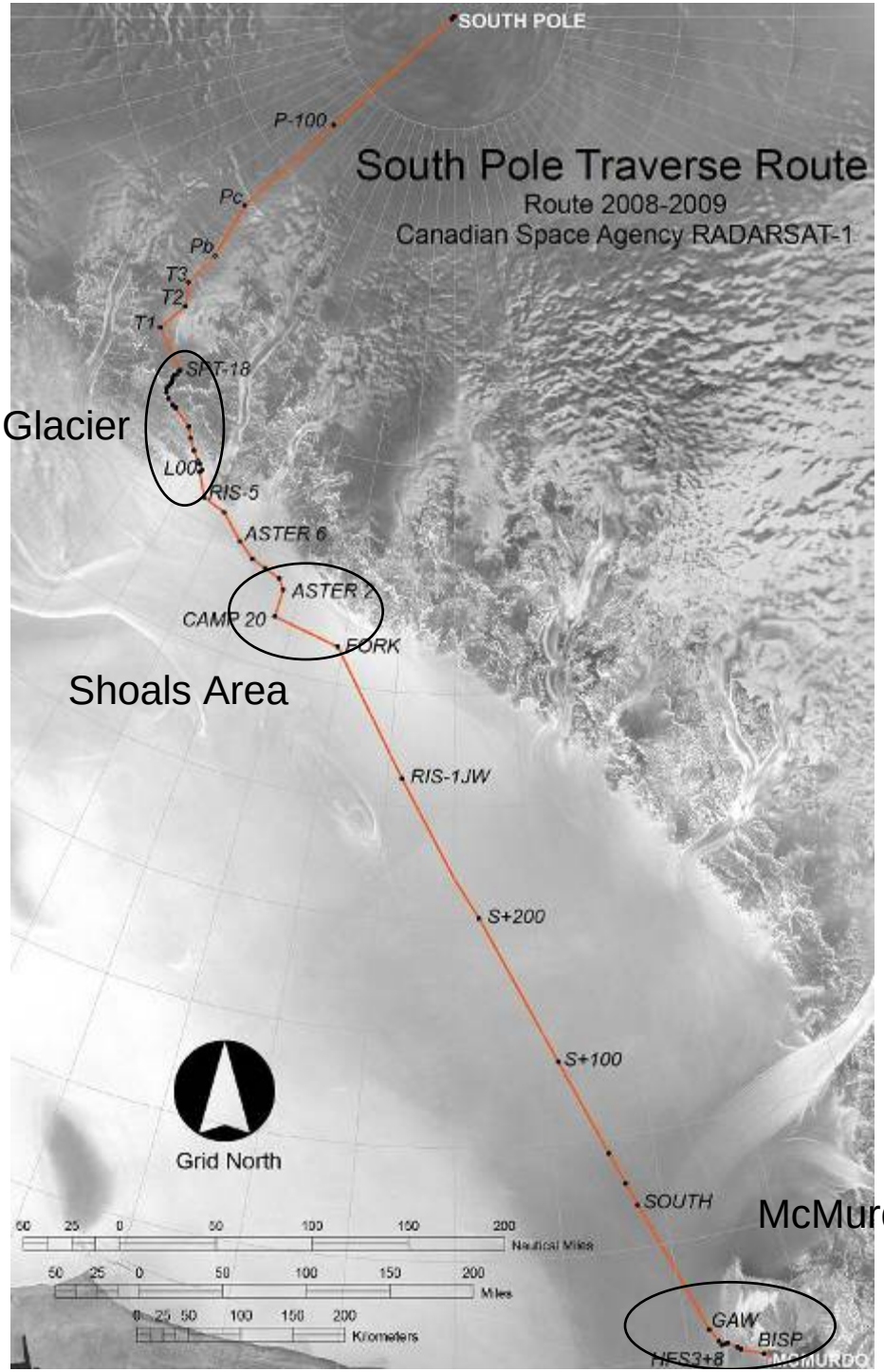

Leverett Glacier

Shoals Area

1,030 miles

27- McMurdo Ice Shelf

621- Ross Ice Shelf

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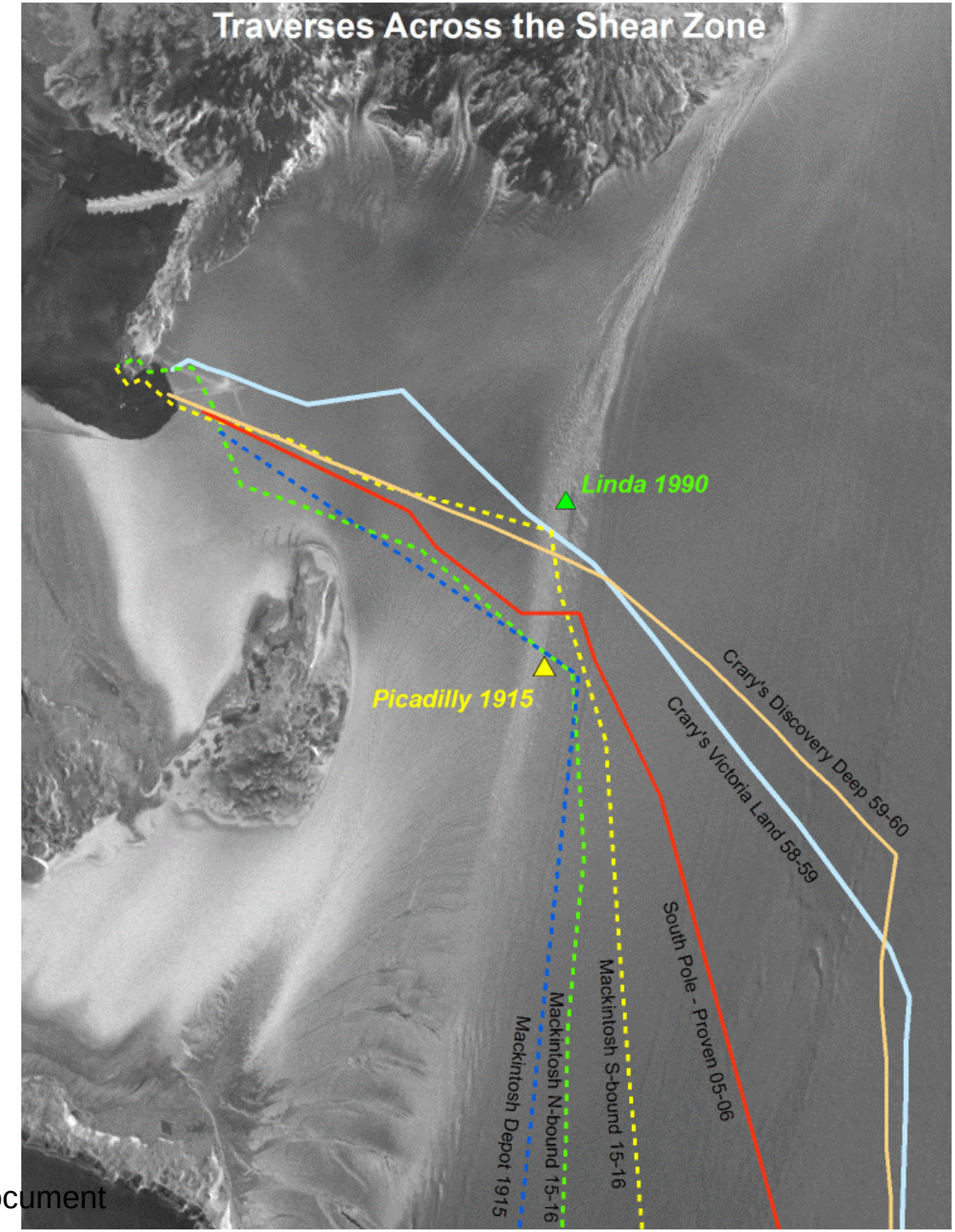
296- Polar Plateau

McMurdo Shear Zone

Traverse route

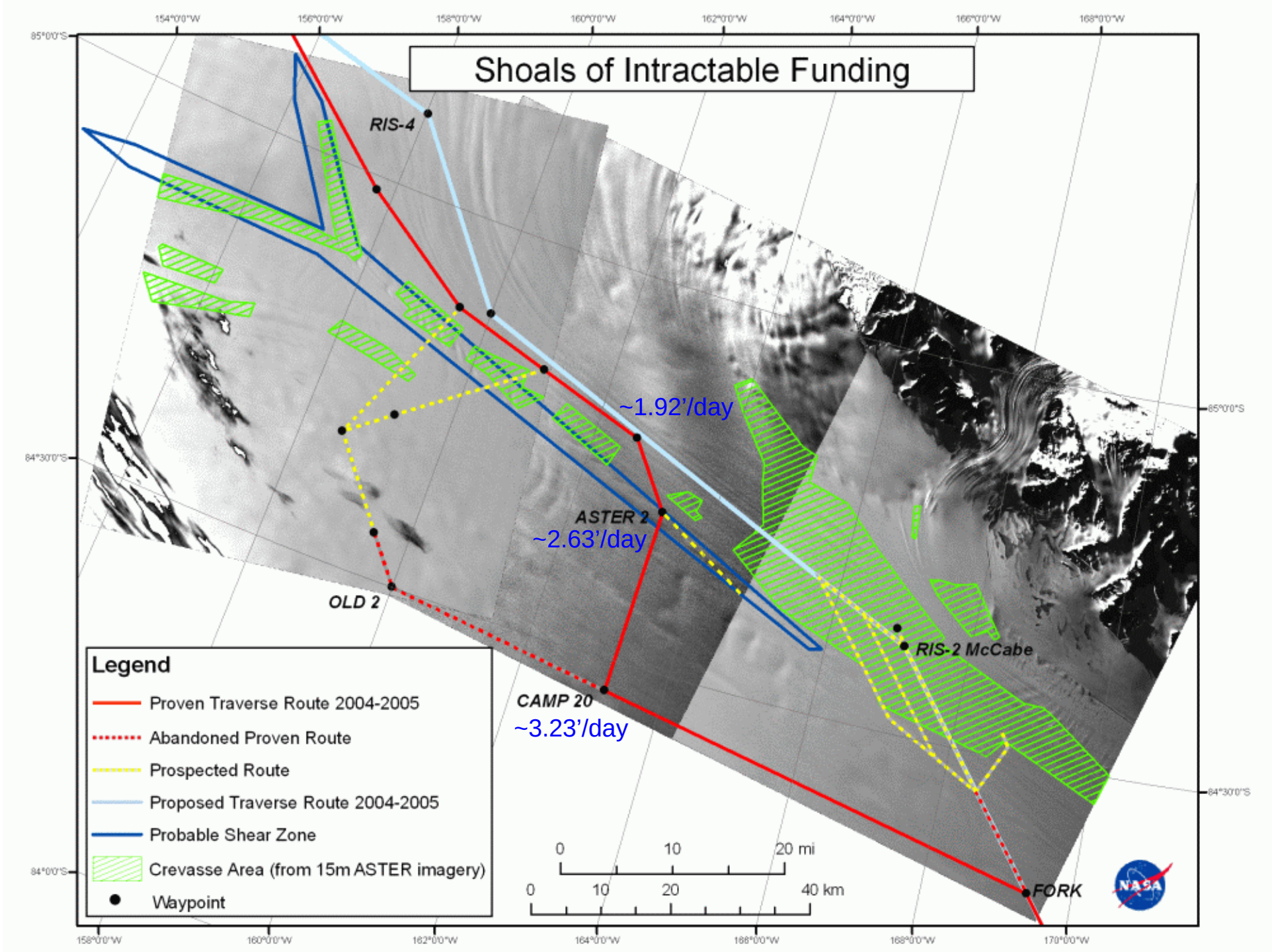
- Several incarnations of a traverse project through the 80s & 90s, Proof-of-Concept Project took 4 years to get to South Pole (‘02 – ’06)
- McMurdo Shear Zone
  - CRREL and John Wright’s team spent the summer of ’02 – ’03 remediating the 3.5 mile trail across the Shear Zone (same trail in-use today, ~40 crevasses)
  - CRREL assists on initial GPR survey assessment each year
  - Blasting and filling of 2 to 3 crevasses each year is required prior to crossing
  - McMurdo Ice Shelf side moves ~2.3’/day (1.45 mi downstream in 9 yrs)
  - Ross Ice Shelf (RIS) side moves ~3.75’/day (2.37 mi downstream)
  - Trail length has increased by 0.31 mi
  - Eventual requirement to move back upstream
- Shoals of Intractable Funding (Shoals area)
  - Area where the Reedy Glacier outflow merges with outflow from other glaciers
- Leverett Glacier
  - Gradual climb with no major crevassed areas to cross
  - Traverse uses a narrow fleet formation for the entire length of the glacier
  - Some areas require shuttling of loads (~10% grade headwall and regions of scouring/reduced traction)

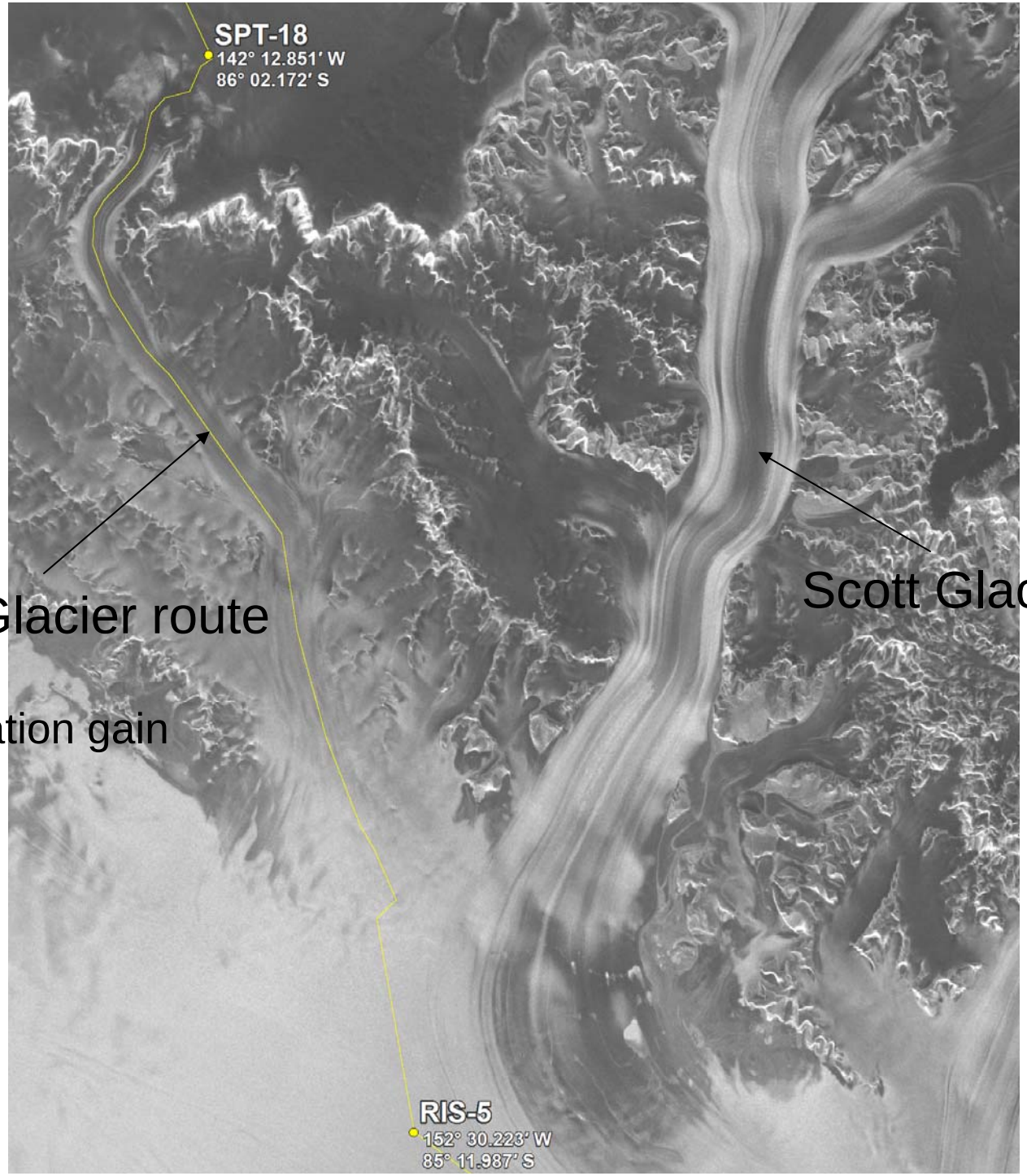


Wright, J., unknown document

Wright, J., (2003). Crossing the Shear Zone: 2002 – 2003

Thur, P., (2008).


Shoals of Intractable Funding
RIS-4
~1.92'/day
ASTER 2
~2.63'/day
OLD 2
RIS-2 McCabe
CAMP 20
~3.23'/day
FORK
Legend
Proven Traverse Route 2004-2005
Abandoned Proven Route
Prospected Route
Proposed Traverse Route 2004-2005
Probable Shear Zone
Crevasse Area (from 15m ASTER imagery)
Waypoint
0 10 20 mi
0 10 20 40 km
154°0'0"W
156°0'0"W
158°0'0"W
160°0'0"W
162°0'0"W
164°0'0"W
166°0'0"W
168°0'0"W
170°0'0"W
85°0'0"S
84°30'0"S
84°0'0"S



Leverett Glacier route

Scott Glacier

6,903' elevation gain

87.66 miles

Traverse route characteristics

- Route conditions vary greatly along the 1,030 mile route
  - Dornick region- short height (1’ – 2’), short wavelength (3’ – 4’) sastrugi with soft snow surrounding them to give the appearance of a smooth surface. This terrain is extremely rough on equipment; short wavelength drifts cause a slamming motion as the vehicles and sleds pass over the crest.
  - RIS swamp- several hundred miles of soft snow that can cause immobilizations (6” – 12” ruts)
  - Lakes district- area on approach to the base of the Leverett that is hard-packed snow/ice
  - Leverett headwall- heavy snow accumulation (>2’ – 3’/yr)
  - Sastrugi National Park- tall (4’ – 5’), long wavelength (15’ – 20’+) sastrugi
  - Plateau swamp- several hundred miles of soft snow (>12” ruts)

Statistics- Deliveries and flights offset

Year	Fuel delivered (lbs)	Cargo delivered (lbs)	Total Lbs delivered	Flights Offset (ACL=26 k lbs)	Fuel unburned by LC-130s (gal)	Traverse fuel burned (gal)	Actual fuel saved (gal)	Traverse efficiency = lbs delivered / lbs burned	LC-130 efficiency = lbs delivered / lbs burned
'05 - '06	-	218,465	218,465	8.4	35,408	27,273	8,135	1.14	0.88
'06 - '07	No traverse activity								
'07 - '08	56,343	-	56,343	2.2	9,132	39,033	(29,901)	0.21	
'08 - '09	805,175	128,570	933,745	35.9	151,339	72,212	79,127	1.85	
'09 - '10	662,382	39,368	701,750	27.0	113,737	62,271	51,466	1.61	
'10 - '11	667,240	-	667,240	25.7	108,144	60,881	47,263	1.57	
'11 - '12- SPoT 1	329,756	83,030	412,786	46.6	196,372	69,629	126,743	0.85	
'11 - '12- SPoT 2	588,476	54,755	643,231	24.7	104,253	38,761	65,492	2.37	
	Ttl LC-130 Flights Offset			170.5	Fuel saved		348,326	1.39	Combined '11-'12
								1.6	4-year avg

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Accomplishments

- Moved >3.6M lbs to / from deep field locations
- Supported the installation of a Science project on the RIS via traverse in ’10 – ’11 that would have been cancelled because of weather that did not allow flights, but was suitable for traversing
- Supported Science on the Polar Plateau and RIS each year with depot’ing / pick-up of cargo
- Established and maintained fuel depots of 27,000 gallons on the RIS (in steel tanks) to extend the range of fixed-wing aircraft
- Partially closed the AGAP South camp via ground instead of with LC-130s, ~900 mi round trip (9,600’ – 11,500’), represents ~ 34 flights
- Established a traverse route to a future drilling camp on the Whillans’ Ice Stream on the RIS

Specific challenges

- Minimizing delays along the trail (immobilizations & general problems)
- High molecular weight polyethylene (HMW) sleds- experienced breakages of plastic sheets in the field during each traverse
- Fuel bladder reliability
- Inefficiency of steel skis (high cost and high weight) has driven innovation
  - Steel fuel tanks ⟶ plastic sleds and flexible transport bladders
  - Steel skis under buildings ⟶ platforms with an air-cushion ride
- Development of a suitable cargo-hauling platform (air-cushion ride)
  - Requires a flexible interface between the HMW sled and the cargo to be carried
  - Tried off-the-shelf boat pontoons in ’10 – ’11; local field trials were promising, but pontoon seams failed after 100 miles of field use
  - Field tests of 1,600+ miles of a custom pontoon system in ’11 – ’12 proved successful; no failures and no air leaks for the entire field season

Future plans

- Deployment of the Whillans' Ice Stream Subglacial Antarctic Research Drilling (WISSARD) project to the RIS in '12 – '13 and '13 – '14
- Attempt to open West Antarctica in '14 – '15 (McMurdo to WAIS Divide via the WISSARD traverse route)
- Attempt 2 round-trips with one traverse platform in '13 – '14 using existing operating techniques

- Incorporate air-cushion technology into support sleds and cargo sleds
- Continue to make technological advances in our flexible sleds
- Implement autonomous lead-follow technology on one traverse platform
  - Testing in '12 – '13 and '13 – '14, hopefully full implementation in '14 – '15
  - Will allow traverse to travel ~19 hours per day w/ same staffing levels
  - Round trip traverse time should go from 58 down to 38 days, removing much of the risk from a tight timeline and allowing non-rushed turn arounds
  - Makes 2 round-trips in one season with one platform much more likely

Opening of West Antarctica