

# Drilling from IceCube to Upgrade

IceCube Upgrade  
NSF Re-baseline Review  
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# Jeff Cherwinka – UW Physical Sciences Lab

- IceCube EHWD System Engineer
  - Joined IceCube 2002
  - 6 trips to South Pole ~9+ months on ice
  - Lead Integration, Verification & Test for EHWD
  - Involved in shipment of EHWD to Pole and initial operation
- LZ Dark Matter Experiment Chief Engineer 2012 – Present
- IceCube GEN2 Project Engineer
- 36 years leading projects to design, engineer, fabricate and install physics research equipment around the world.



# Drilling for the Upgrade Builds on IceCube Experience

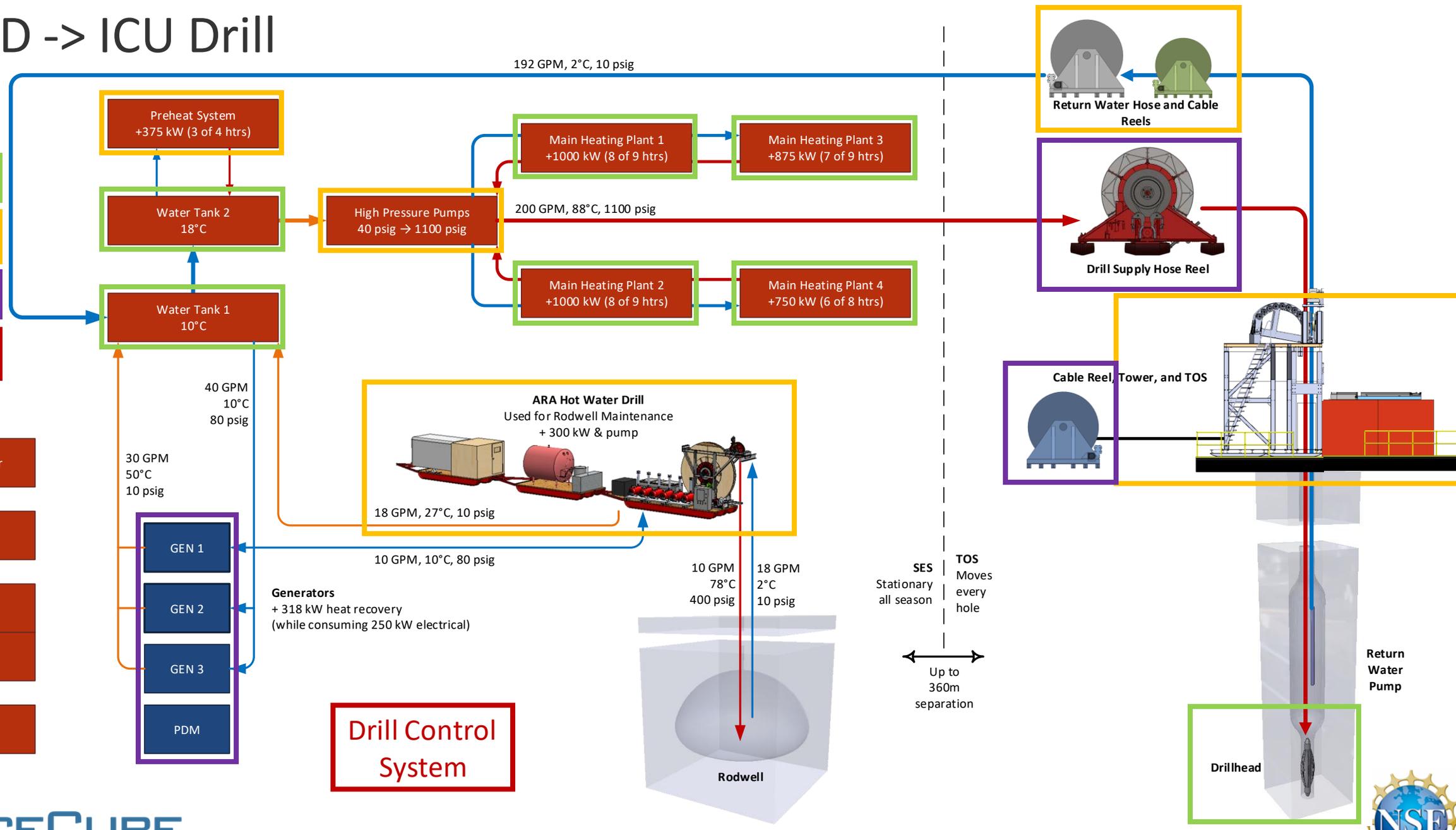
- The Upgrade Drill will be a refurbished version of the Enhanced Hot Water Drill (EHWD) used to drill the 86 existing IceCube holes.
  - 760 lpm (200 gpm) of 88 C (190 F) water -> 4.7 MW thermal, 0.3 MW electric
  - 2.2 m/min maximum drill speed
  - Continuous operation with 30 people (3 shifts of 10)
- Much of the EHWD was left at the South Pole at end of drilling in 2011 and needed evaluation and refurbishment
- Some of the equipment went to other projects such as WISSARD and needed more substantial rework or complete replacement
- Many people that worked on EHWD design fabrication and operation are now on the ICU drill team

# EHWD -> ICU Drill

Level of Rework

- Minor
- Moderate
- Major
- NEW**

- Other Buildings:
- Drill Control Center
  - Electrical Shop
  - Mechanical Shop
  - MECC



# IceCube Can Drill & Install every 48 hours

Demonstrated repeatable drilling & installation with repair and maintenance for 20 holes in a season. Achieving this rate required learning and we still remember 2003-4 Hose reel shipped to Pole and assembled

2004-5 **1x** Hole, Most of season spent assembling drill, then Drill & Install  
Heat Transfer limit -> higher nozzle velocity

High Pressure pump motors overheating -> new motors

2x 12+ hour shifts, 18 drillers -> 3x 9 hour shifts 30 drillers + manager

2005-6 **8x** Holes - Major revisions to drill (Hose, Tower), Start of first hole Dec 19  
Air in fuel -> pressurized fuel system

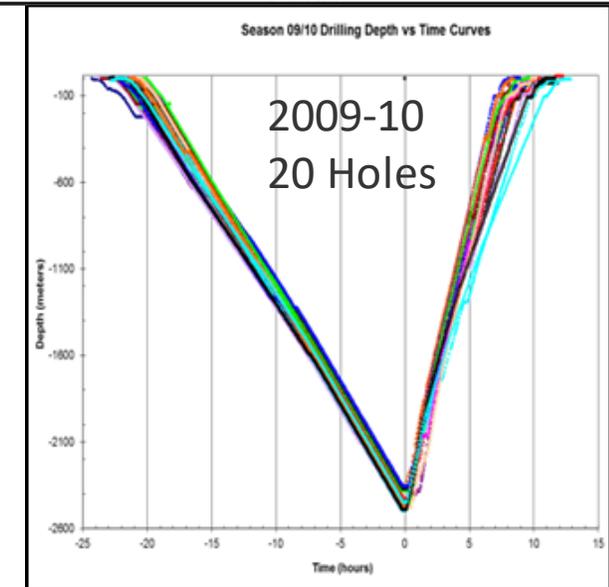
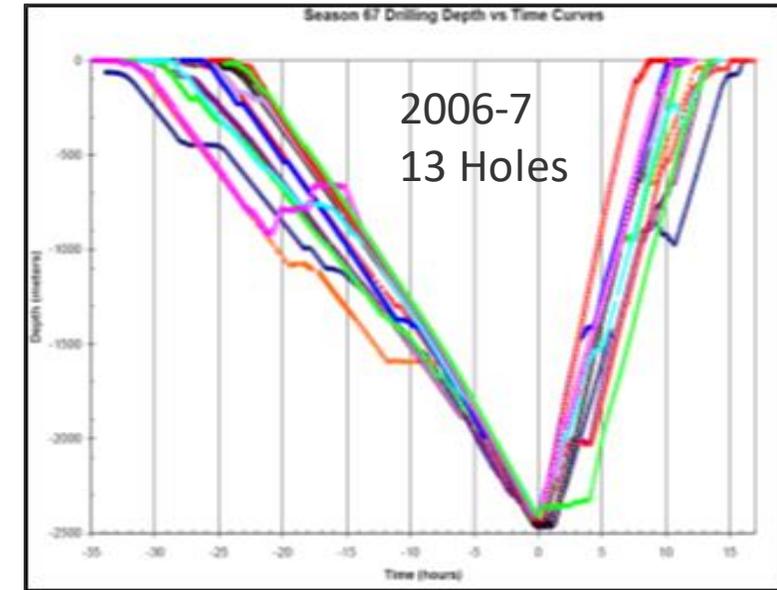
2006-7 **13x** Holes – Start of first hole Dec 11, 8 hose sections replaced, Firm in series  
Hose failures -> Heat hose to -50 C or above during night  
Firm drilling takes a lot of time -> Independent Firm Drill (IFD)

2007-8 **18x** Holes - Drilling limited by fuel availability, Start first hole Dec 5  
Hole modeling & logging allows reduced lifetime and fuel savings  
Better management of rod well and idle heat usage for fuel savings

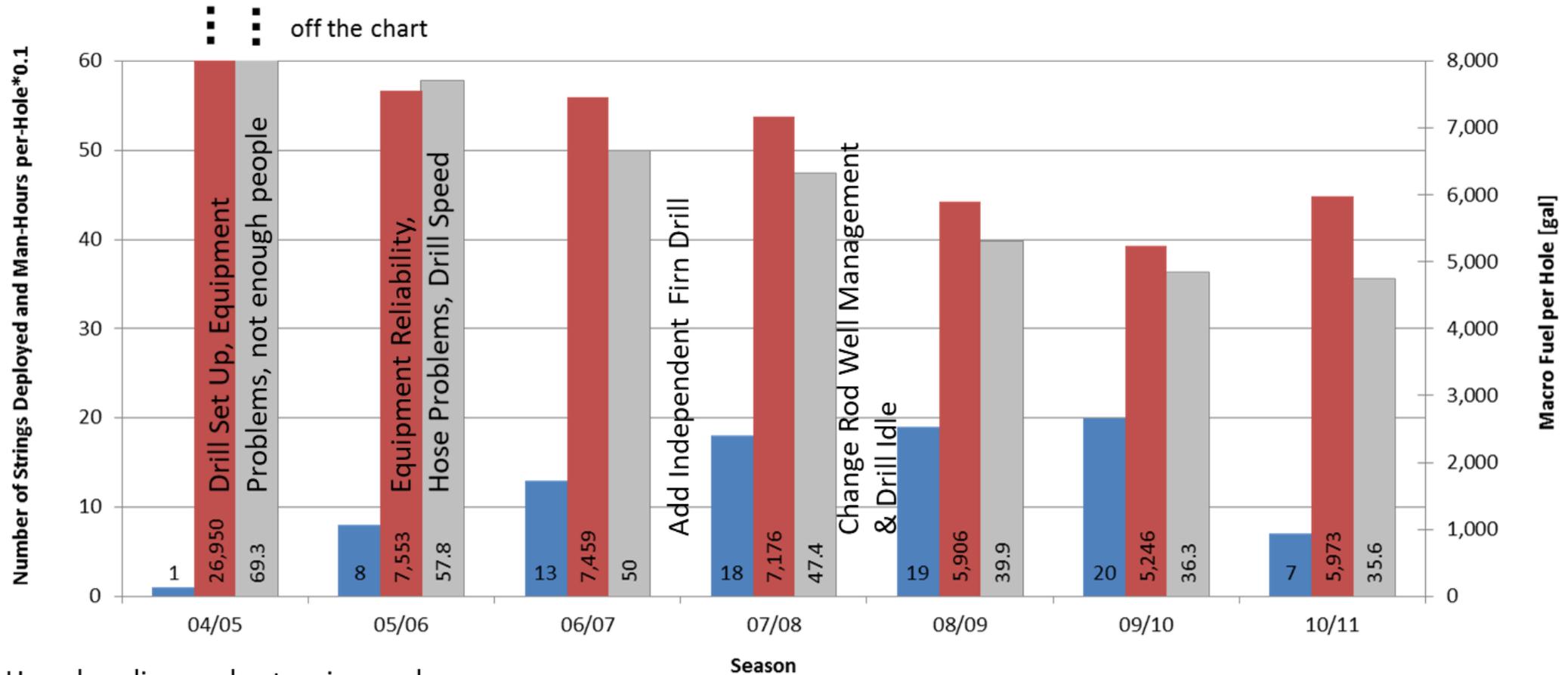
2008-9 **19x** Holes - Experienced crew & optimized equipment yield consistent holes

2009-10 **20x** Holes - And it's repeatable

2010-11 **7x** Holes Pack drill for storage and disposition to WISSARD



# IceCube Drilling and Deployment History



Hose bending under tension and pressure

PM motor demagnetizing

Drive Programming

Air in Fuel System



# Lessons Learned & Implemented

- ❖ Water quality was not a criteria for EHWD. Water contamination from particulates, and bubbles from entrained air have proven to be issues and will be improved
- ❖ The northern hemisphere support group did help solve problems and improve solution implementation time. This was a dedicated person on shift in the north with a phone.
- ❖ Testing and training in the drill test bed at PSL helped avoid problems in the field and helped resolve them when they occurred. This facility has been retained and will continue to be used. All drillers and most installers get some training before heading to the ice.
- ❖ A meeting of all drillers before start of drilling to insure the equipment and people are ready proved to be helpful.
- ❖ Shift Lead with Deputy Lead as safety officer worked well. Drill Manager separate.
- ❖ Restarting the EHWD has shown we could have done better at documentation and archiving. The upgrade is working to improve this.
- ❖ Reliable snow machines are important for efficiency and safety.
- ❖ DOMs proved to be extremely reliable.

# People are Key

- ❖ Getting good people is important
  - ❖ Keeping Experienced people is even more important
  - ❖ ICU is fortunate to have many experienced people still available
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- Good Pay
  - Year Round Insurance
  - Summer Training
  - Treating people well



# Logistics Experience

- ❖ The Logistic path to the South Pole is long and there are many serial steps. Every step had an issue at some point in the project. These are often out of the projects control
- ❖ Starting things into the Logistic path as early as possible yielded the best results
- ❖ Communicating with people as directly as possible helped eliminate and resolve problems
  - ❖ Air National Guard officers visited UW-PSL to look at cargo and talk about issues
  - ❖ RPSC also visited PSL and invited IceCube planners to their offices in Denver to work out details
  - ❖ IceCube had direct contacts at Port Hueneme to talk about arrival and shipment details
  - ❖ IceCube had direct contacts in Christchurch to talk about arrival and shipment details
- ❖ There were delays getting people to the South Pole... plan some float
- ❖ There were delays getting cargo to the South Pole... plan some float
- ❖ The project was completed successfully!

# Drilling Requirements Comparison

	EHWD (Gen1)	ICU	Ratio (ICU/Gen1)
<b>HOLE DEPTH</b>	2450 m	2600 m	1.06
<b>HOLE SIZE</b>	45 cm dia for 37 hr lifetime	52 cm dia for 45-55 hr lifetime	1.38 (volume)
<b>TIME TO DRILL HOLE</b>	34 hr (typical)	53 hr (average)	1.57
<b>ARRAY</b>	125 m hole spacing	22 m hole spacing, center of IceCube	
<b>ICE QUALITY</b>	NA	Better and less bubbles	
<b>HOLES</b>	86 holes in 7 seasons	7 holes in 1 season	
<b>DRILL TEAM</b>	30	28	
<b>LOGISTICS</b>	LC130, primarily	Vessel and Traverse, primarily	
<b>INSTRUMENTS</b>	60 per string	115 per string	1.92

# SUMMARY

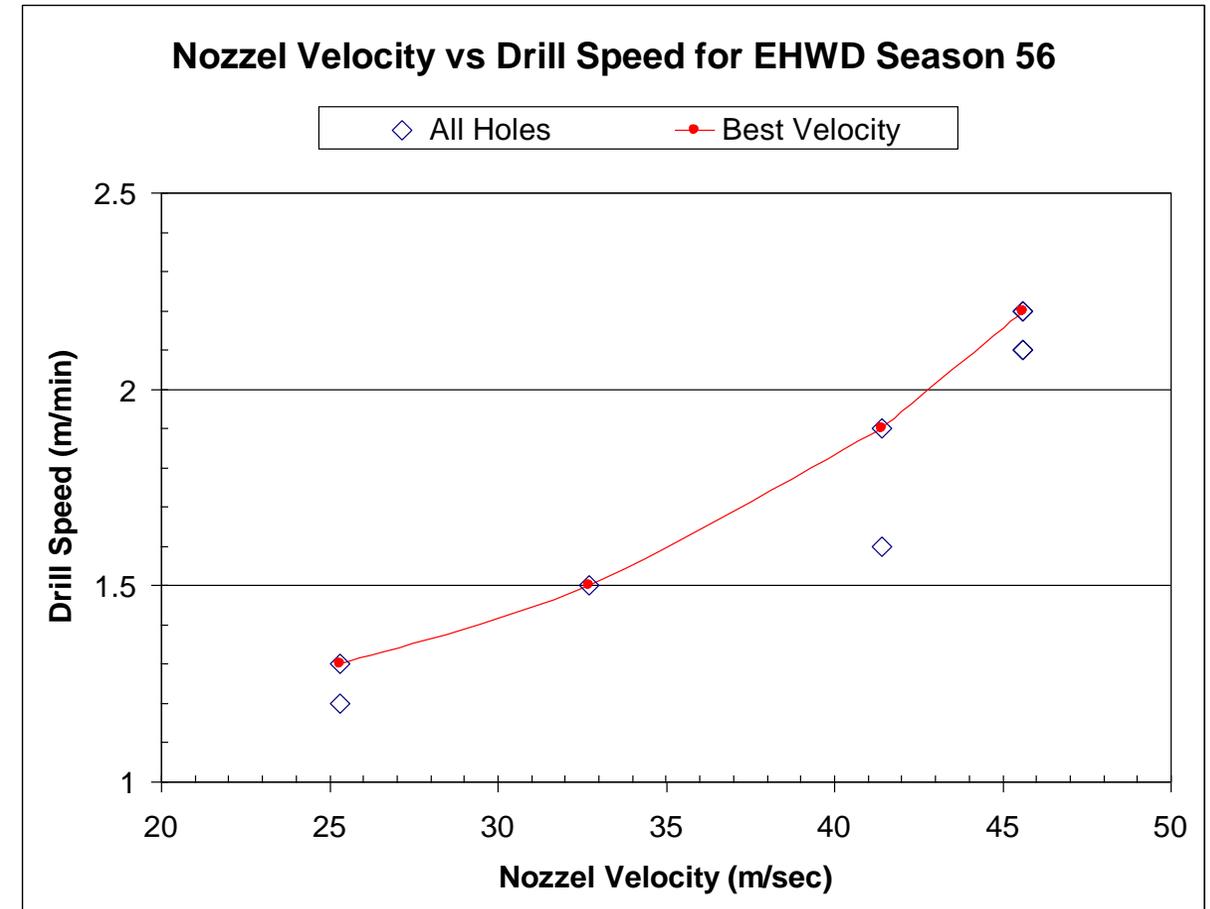
- IceCube GEN1 drilling and deployment was not easy and it had a very difficult first year, but then continuous improvement led to consistent performance above expected installation rates.
- The lessons learned have already been incorporated into improvements in the EHWD equipment and should benefit the ICU.
- The rest of the knowledge from those hard learned lessons is still in the hearts and minds of the many member of the ICU team that were involved in the original IceCube construction.
- Upgrade drilling, using a refurbished EHWD, requires holes that are a little deeper and larger, but is a straight forward extension of proven drilling methods.

# Backup Slides



# Making measurements allowed improvements

- ❖ While we attempted to model hole drilling with CFD we learned the most with experiments during drilling. Nozzle Velocity is key to maximum drill speed
- ❖ We also logged holes to verify and improve hole drilling and freeze back model
- ❖ ICU will study different reaming strategies and water quality impact on the hole ice
- ❖ We are thinking about other things that might be useful for GEN2 like freezeback pressure and it's mitigation



# Enhanced Hot Water Drill (EHWD)

IceCube, South Pole 2004-2011



## Seasonal Equipment Site (SES), aka Drill Camp



11/3/2021

IceCube Upgrade Drill Overview - T. Benson



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# Enhanced Hot Water Drill (EHWD)

IceCube, South Pole 2004-2011



## Tower Operations Site (TOS)



11/3/2021

IceCube Upgrade Drill Overview - T. Benson



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# Operations

- Drill season operations
  - See Dar's talk
- Hole life cycle
  - Firm Drill
  - Deep Drill + Ream
  - Turn over to Deployment Team
  - Move reels to other TOS
  - Repeat
- Deep Drill and Ream
  - SES team ensures a reliable and steady flow of hot water is supplied to TOS
  - TOS team drives drill and maintains safe/smooth operation of reels
  - Driving drill involves constant monitoring of system parameters and referencing drilling strategy speed charts
- Other Operations
  - Instrument installation
  - Hole moves
  - Maintenance and repair

