NEW TECHNOLOGIES NEED HAZARD ANALYSIS

Greg Nesmith, PE, CFSE
Dow Chemical

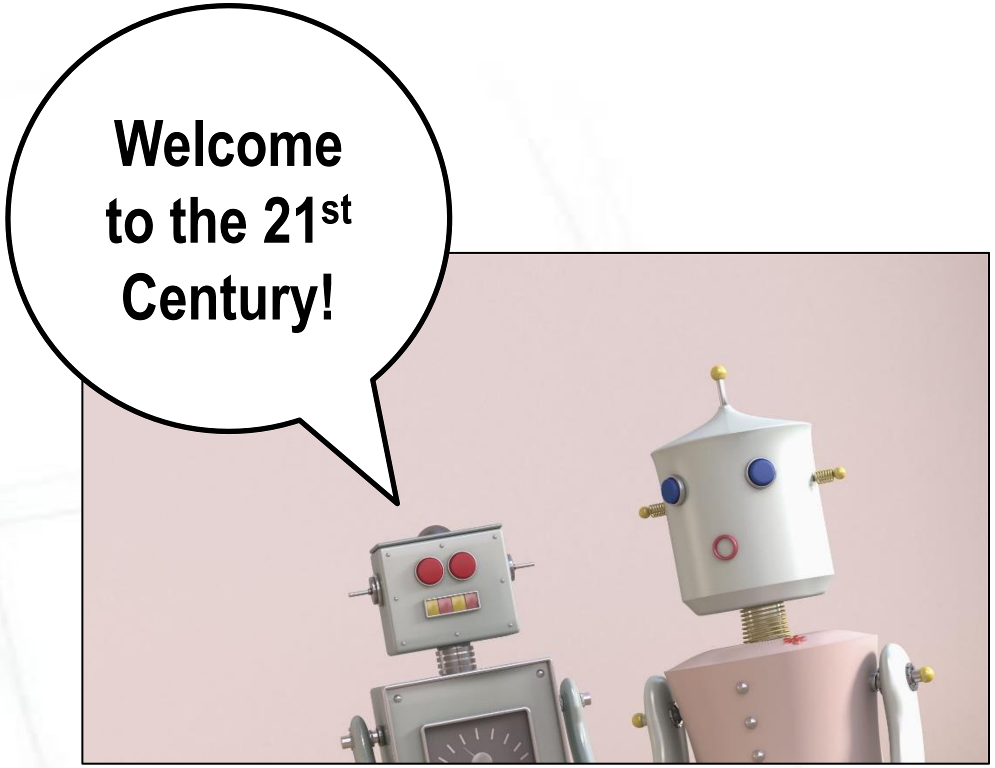
Process Safety
Risk Management

Greg Nesmith, PE, CFSE

- The Dow Chemical Company
- Process Safety Principal
- BSChE - University of Arkansas (1990)
- 34 years with Dow Chemical in Plaquemine, Louisiana
- Process Safety Tech Center (2007 – present)
  - Fault Tree Analysis SME (2014 – present)
  - Process Safety Training Leader (2016 – present)
  - Instrumented Protection Systems SME (2017 – present)
  - Manufacturing 4.0 Process Safety Focal Point (2018 – present)
- Certifications:
  - Louisiana Professional Engineer (1997)
  - MAIC Six Sigma Black Belt (2000)
  - Certified Functional Safety Expert (2017)
- Advocacy:
  - CCPS/EPSC Big Data
  - AIChE Safety and ChemE Education (SAChE)
  - IEC 61511/ISA-84 Committees

Evolution of Industry

Industrial Phase	Century	Key Technologies
1.0	18th	Machines, steam and water power, corporation
2.0	19th	Electricity, internal combustion engine, mass production
3.0	20th	Transistors, circuits, computing, software
4.0	21st	Internet of things, cyber systems, artificial intelligence

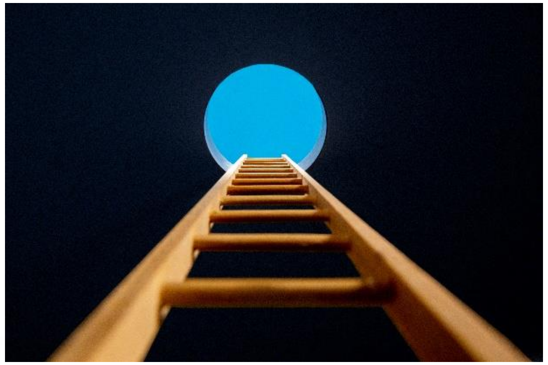

Welcome to the 21st Century!


VISIBILITY
AGILITY
RELIABILITY
INNOVATION
Technically Skilled Workforce
MANUFACTURING 4.0
Physical and Cyber Safety
ANALYTICS/EMI
MOBILE
ROBOTICS
PC/PA/E&I
DIGITAL THREAD/ VISIBILITY

AGENDA

- Case for Change
- History: Dow and Robotics
- Robotic Technology Applications
- Hazard Identification
- Implementation of a Corporate sUAS/Robotics Program
- Recap
- Q&A

Case for Change



According to data collected by the U.S. Department of Labor…

- ~ 150 fatalities occurred during confined space entries in 2018
- > 800 workplace fatalities were attributed to falls to a lower level in 2020

Table 1. Fatal occupational injuries involving confined spaces, 2011-2018

Year	2011	2012	2013	2014	2015	2016	2017	2018
Fatal work injuries	120	88	112	116	136	144	166	148

Table 2. Fatal occupational injuries for selected events or exposures, 2016-20

Characteristic	2016	2017	2018	2019	2020
Fall, slip, trip	849	887	791	880	805
Fall on same level	134	151	154	146	136
Fall to lower level	697	713	615	711	645
Fall from collapsing structure or equipment	65	48	50	37	36
Fall through surface or existing opening	87	85	83	95	63

Break-through technologies are needed to achieve these goals.

History: Dow and UASs/Robotics

- 2014: Initial projects targeted use of Robots and sUAS
- 2015: sUAS technology program began
- 2016: Piloting of sUAS/robotic technology
- 2018: Full deployment of Dow sUAS program, completing
    - From 2018 through 2021: over 5000 flights,
        - Over 4000 for CSE
        - Over 1000 for elevated work or Site mapping
- 2018-21: Full deployment of the Robotics program, completing:
    - From 2018 through 2021: over 6000 Confined Space Entries avoided,
        - Over 4000 by use of sUAS
        - Over 2000 by use of Robots, Probes, and cameras
- Savings of tens of millions of dollars in avoided:
    - Downtime/productivity losses
    - Inspection/maintenance costs
    - Scaffolding costs

Robotic Technology Applications

- Photography and video
- Mapping
- Facility/structural inspections
- Insulation integrity/Process performance reflective of heat generation
- Sampling
- Non-destructive testing
- High-pressure cleaning
- Cutting and drilling
- Security/surveillance
- Emergency response
- Search and rescue
- Construction monitoring
- Accident investigations

Exciting tech! Let's do this!

What do you mean by "Something could go wrong"?

Photo of drone with dead battery inside process vessel sitting in a pool of potentially hazardous process liquids

What went wrong

Error	Root Cause
Dead battery	Flight path did not account for internal obstructions; poor planning
Hazardous Area Classification incorrect	Misunderstanding of internal HAC; lack of expert review; 2nd drone also an error
Drone materials of construction incompatible	No reactive chemicals review
Gas detection at entrance only	Emphasis on people exposure and not equipment compatibility
Static electric discharge from propellers not considered	No formal hazard identification or risk assessment

Let's try this again…

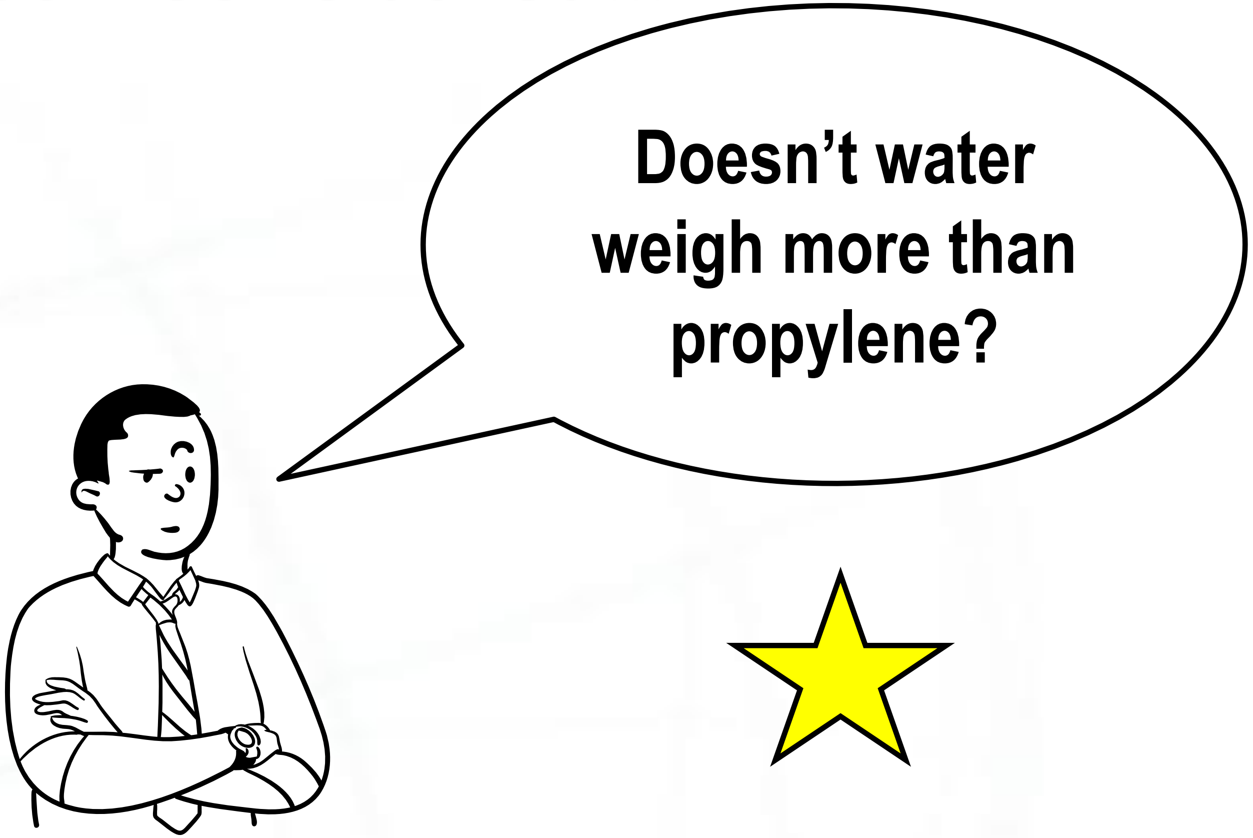
The Submarine Robot (Mini-Sub)

No Confined Space Entry!

Mini-Sub Hazard Identification

Issue	Response/Result
Flammability	Propylene removed; filled with water
HAC and Ignition Sources	Filled with water; no oxygen for ignition
Human exposure to chemicals	Decontamination of mini-sub upon removal reviewed and approved
Adding/removing robot	Safe procedure developed and approved
Other issues	Consulted with vendor; approved
Reactive chemicals	Robot parts are compatible

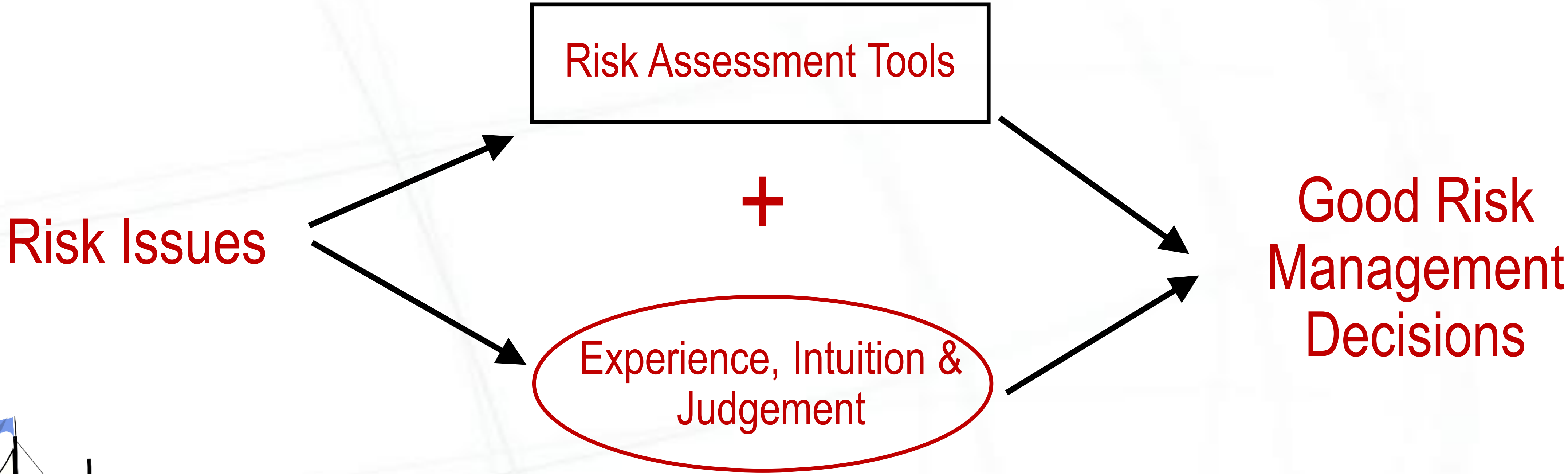
Then finally, someone asked…

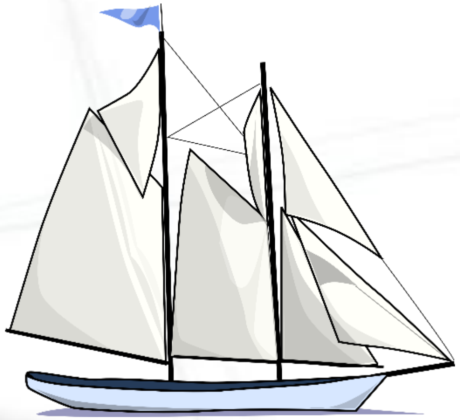


Use a multi-discipline team for your reviews!

What is Risk Management?

Risk Management requires a combination of good Risk Assessment tools, Experience, Intuition, and Judgment

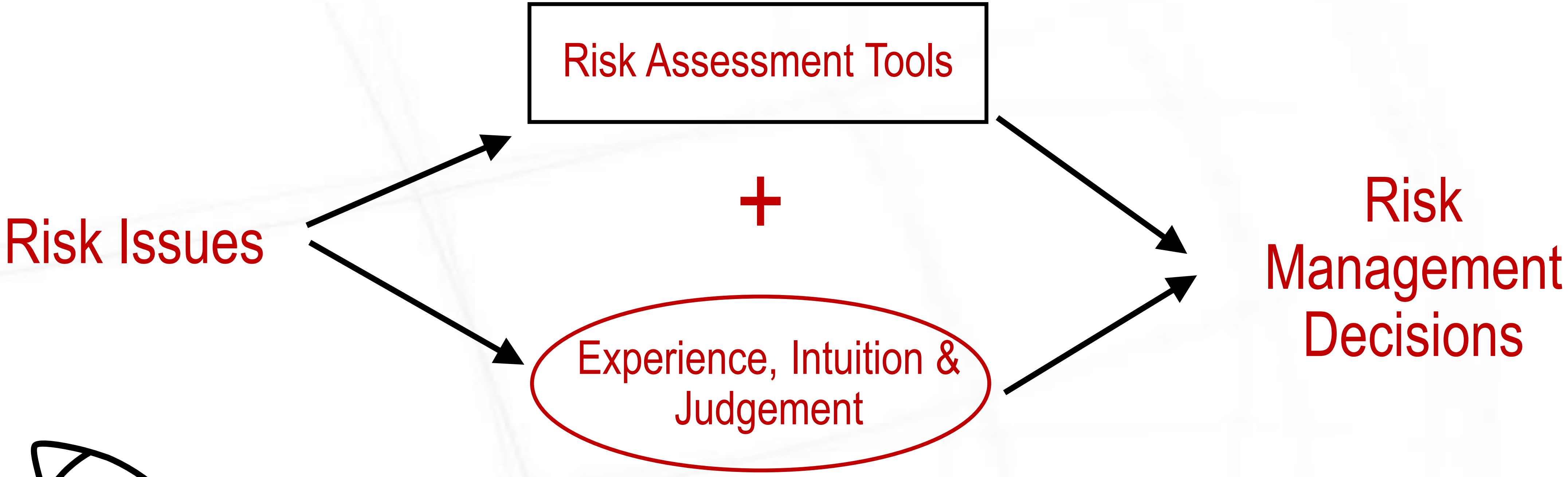


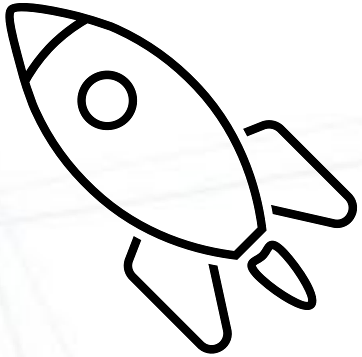


Examples (Sailors):

- **Some Sailors use only the charts, radar, etc. to make decisions,**
- **Some only look out the window and use gut feel,**
- **But the best decisions use a combination of both.**

New Technologies = New Risks!





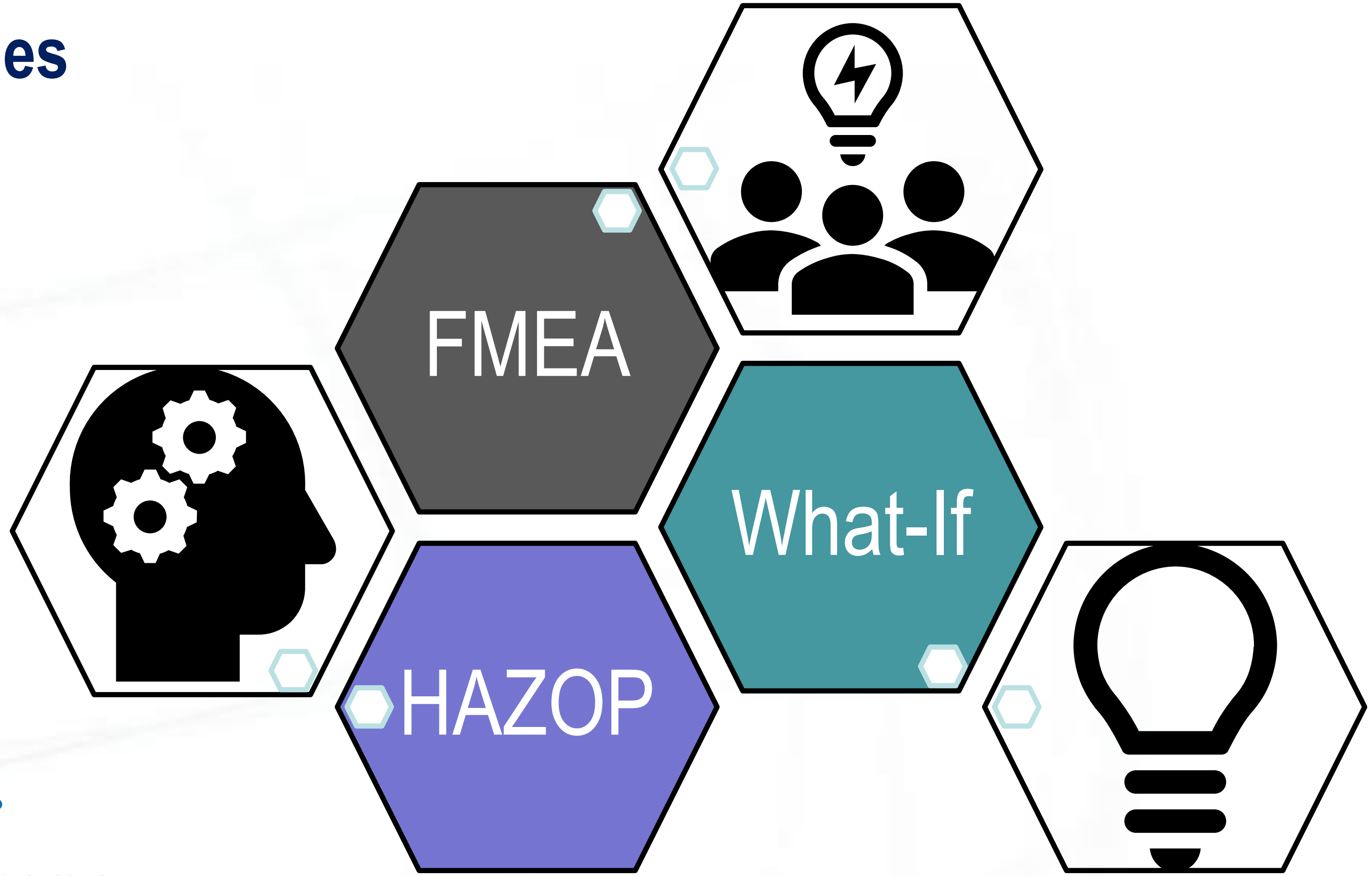
Fundamental Challenges with New Technology:

- Lack of historical data limits the tool set and effectiveness of tools
- Lack of experience hinders our intuition and judgment

Hazard Identification Tools

Brainstorming Tools & Techniques

- Failure Modes and Effects Analysis
- Hazard Operability Study (HAZOP)
- What-If Analysis
- Other techniques?



Put together a winning team.

Emphasize quantity over quality.

No idea is too absurd to consider.

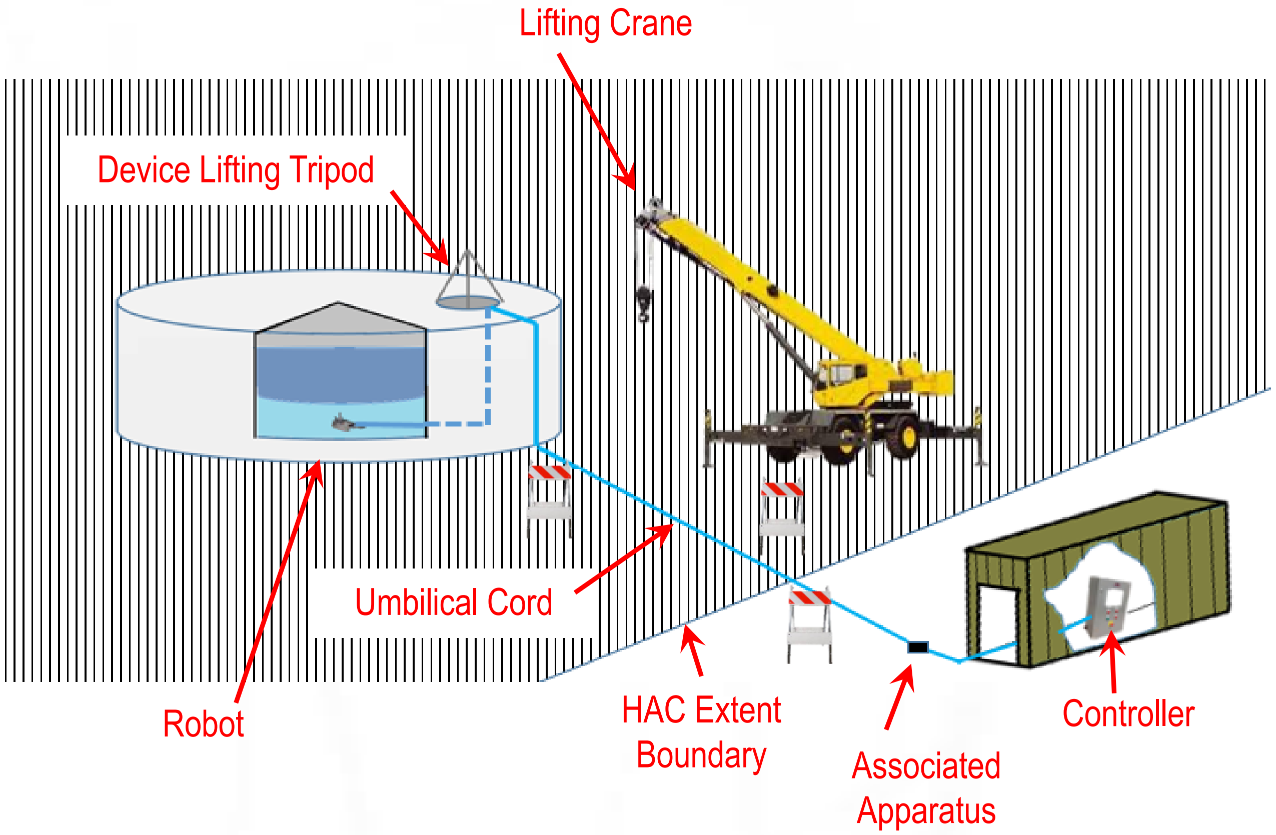
Use techniques that involve everyone.

All ideas become property of the team.

Use of sUAS and Robots - Basic Considerations

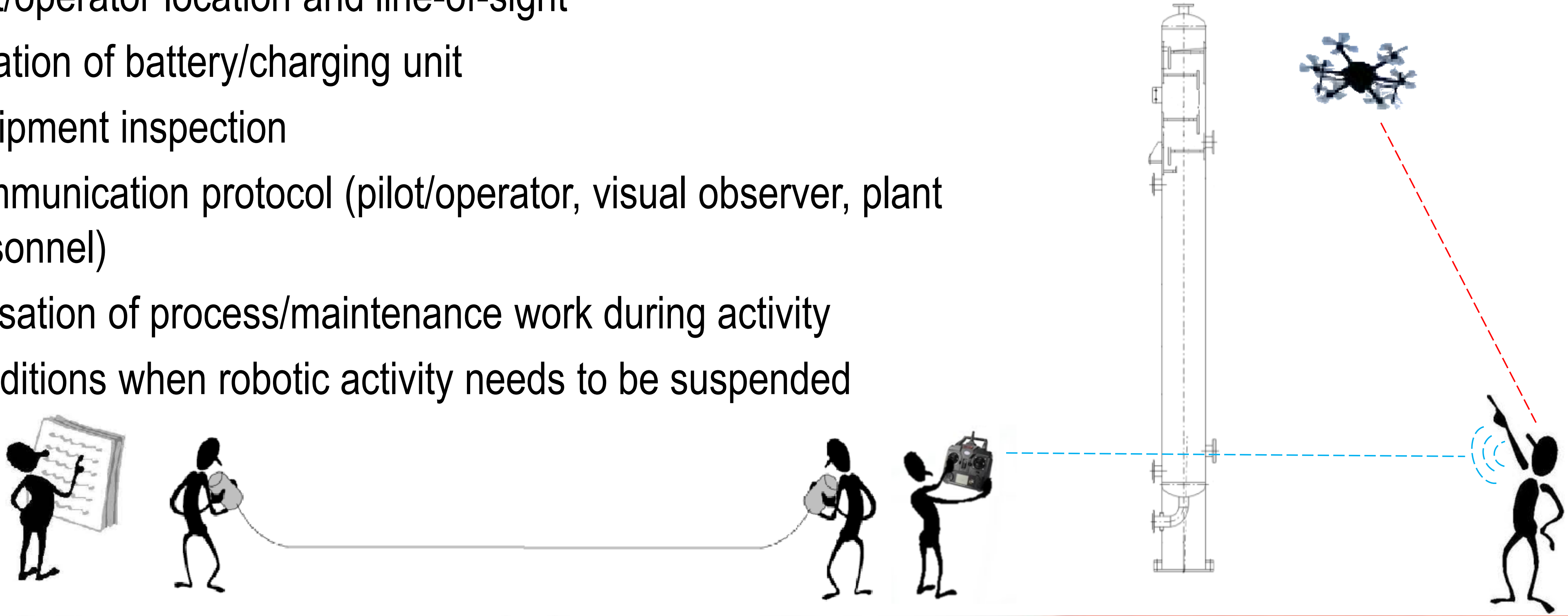
Pre-planning of robotic operations is critical:

- What are the objectives of the operation?
- What device(s) will be needed?
- Who will be conducting the activities?
- Where will the activity occur – and what hazards might exist or be created?
- What processing operations might occur during the same time as the robotic activity?



Use of sUAS and Robots - Basic Considerations

- Pilot certification and sUAS registration
- Data transmission frequency
- Pilot/operator location and line-of-sight
- Location of battery/charging unit
- Equipment inspection
- Communication protocol (pilot/operator, visual observer, plant personnel)
- Cessation of process/maintenance work during activity
- Conditions when robotic activity needs to be suspended



Use of sUAS and Robots - Travel Path Considerations

- No-fly zones or private land
- Elevated structures
- Flight instability zones
- Nesting birds
- Collision with critical equipment
- Snagging of robotic cables
- Loss of power
  - Launch/battery charge locations
  - If the device fails, where will it land?
- *Potential condition changes over time*

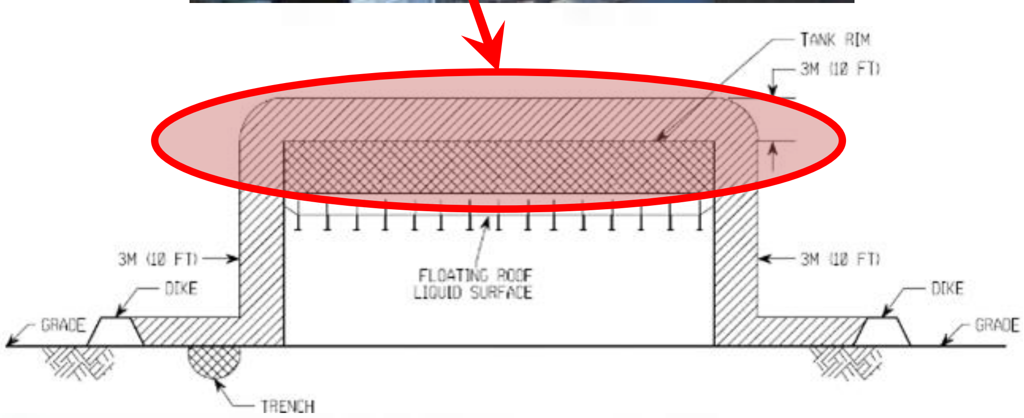
Plan travel in four dimensions!




Use of sUAS and Robots *External* to Process Equipment

Will the device pass through/over, or conduct operations in, a classified area?

- Sumps
- Trenches
- Tank breather vents
- Pressure relief devices
- Process vents
- Open floating roof tanks



Three options for working in classified areas:

- Select a system that is rated for the HAC of the travel route and the inspection area
- Remove combustible/flammable materials to temporarily change the HAC rating
- Utilize a Hot Work Permit and safe operating discipline

Best Practice – Draw the travel path on a copy of the Hazardous Area Classification Drawing (HACD), indicating flight elevations and hazards to avoid.

Use of sUAS and Robots – *Is the Device Properly Rated?*

Caution:

- Some suppliers have incorrectly represented their equipment as suitable for hazardous (classified) areas.
- Use of individual, certified components does not make a device certified.

Real Example:
A vendor indicated that a robot was certified for Class I, Division 2 service because the camera component mounted on the robot was certified. However, the assembled robotic unit was never certified as a system - and was actually not suitable for use in a hazardous (classified) location since the wiring methodology and power management methods were not compatible with the HAC service.

- US: Nationally Recognized Testing Laboratory (NRTL) certification
- ATEX: Notified Body (NOBO) certification for Zone 0/1 or Zone 20/21*
- IECEx: Notified Body (NOBO) certification for Zone 0/1/2 or Zone 20/21/22

*Declaration of Conformity may be acceptable for Zone 2/22 applications with SME support.

Use of sUAS and Robots *Inside* Process Equipment

Internal operations present unique challenges, with the potential for:

- Injury/exposure to personnel introducing/removing the device.
- Residual flammable, toxic, pyrophoric, water/oxygen-reactive materials, especially in low spots, column packing, and hard-to-clean areas
- Damaging process equipment.
- Contaminating process equipment.

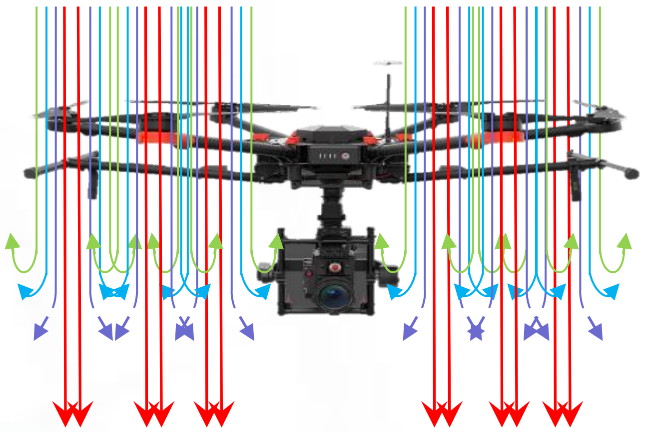
External sUAS

Internal sUAS

Internal Use – “Prop Wash”

“Prop wash” (air movement from sUAS rotors) can present special hazards:

- Prop wash (and hydroblasting, vacuuming, etc.) could release trapped ignitable material from residual sludge or create an ignitable dust cloud from combustible dust layers.
- Particulate movement or atomization of residual material from prop wash can increase the internal concentration of flammable materials.
- Prop wash can create static electricity; be cautious if the equipment contains low Minimum Ignition Energy (MIE) materials.
- Prop wash can create combustible dust clouds.

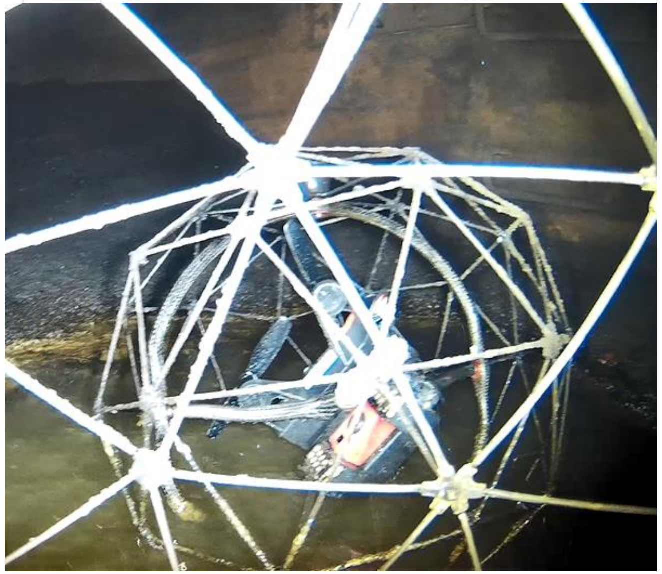


Dow had not yet evaluated commercial sUAS for use in combustible dust applications.

Use of sUAS and Robots *Inside* Process Equipment

Other important safety considerations for internal operation:

- Emptying and cleaning doesn't change the surrounding HAC.
- Ventilation inside equipment may create flight instability.
- Hot internal surfaces; certifications have temperature limits
- Lack of line-of-sight; challenging flight path
- Equipment failure inside of the process equipment



Real Example:

A sUAS was in use inside a process vessel. However, it was difficult for the pilot to maneuver around obstacles, and the operation required more flight time than expected. When the low power alarm was received, the pilot immediately began the extrication flight. Unfortunately, because of the complicated return flight path, the sUAS ran out of power before it could reach the manway, and it fell into the bottom of the vessel. Retrieval was later successful by "hooking" the failed UAV with a "rescue" sUAS.

Robotics *Inside* Process Equipment WITH Process Chemicals

Potential issues:

- Area below tank level may be unclassified, but device may pass through classified headspace. Manage carefully.
- Inerting may create other process hazards or asphyxiation risks.
- Device may contaminate the process chemical.
- Process chemical might damage the device.
- Decontamination plan is required - or the device might be disposable.

Real Example:
A plant was evaluating the use of a robot to inspect a tank without removing the process chemical. The metallic components were evaluated and found to be compatible with the process chemical. However, it was subsequently determined that the soft, elastomeric components of the robot would have dissolved while immersed in the process material.

Implementation of a Corporate Robotics Program

- **Corporate Standard**
  - General policies and guidance
  - Roles and responsibilities
  - Legal requirements
  - Limitations and boundaries for use/when expert review/approval is required
  - Expert subject matter contacts
  - Management of Change

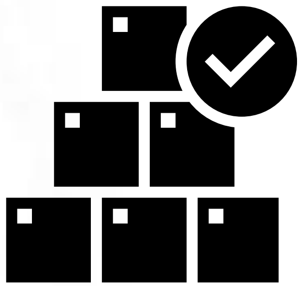
- **Approved Device/Contractor List**
  - Pre-approved robotic devices (and for what applications they are approved)
  - Pre-approved contractors (by region)

- **Training**
  - By role (e.g., general awareness, approver, operator)
  - Multiple languages

- **Communicating "Success Stories" and "Lessons Learned"**

Implementation of a Corporate Robotics Program

- **Checklist(s)**
  - Hazard identification/mitigation
  - Documented flight path on HACD; include hazards to be avoided
  - Permit requirements
  - PPE requirements
  - Conditions requiring cessation of work
  - Emergency retrieval plan
  - Verification that device and pilot are properly registered/certified
  - Pre-operation equipment inspection
  - Communication plan (pilot/operator, visual observer, plant personnel)
  - Documentation of review and approval by key individuals



Recap – Identifying Hazards

- History may be limited but learn from mistakes. Investigate and leverage learnings.
- Intentionally search for hazards BEFORE employing any new technology in a processing area.
- Use organized, rigorous hazard identification tools and multi-disciplinary teams to prevent incidents before they occur.
- Use corporate standards, checklists, approved vendor/equipment lists, training, and a communications plan to execute new tech safely.

Thank you for your attention!

ANY QUESTIONS?

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