UTC Power
A United Technologies Company

Status of Hydrogen Quality Standards

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History

- The existing standards are/were:
  - MIL-PRF-27201C
  - CGA G-5.3
  - JIS K0512
  - Title 13 CCR Section 2292.7

History (Cont)

- MIL-PRF-27201C
  - This standard is for a propellant grade.
  - It is for Hydrogen with a liquefaction processing step
  - The standard covers the liquid and vapor state
  - NASA uses this standard (or earlier versions)

History (Cont)

- CGA G-5.3
  - It is for Hydrogen with a liquefaction processing step
  - 4 grades as vapor
    - “B” General industrial applications (99.95%)
    - “D” Hydrogenation and water chemistry (99.99%)
    - “F” Instrumentation and Propellant (99.995%)
    - “L” Semiconductor (99.999%)
  - 3 grades as liquid
    - “A” Standard Propellant (99.995%)
    - “B” High Purity Propellant (99.999%)
    - “C” Semiconductor (99.9997%)

History (Cont)

- JIS K-0512
  - It appears to be for Hydrogen generated by electrolysis
  - 4 Types
    - “1” purity $\geq$99.9999% (6-9’s)
    - “2” purity $\geq$99.999% (5-9’s)
    - “3” purity $\geq$99.99% (4-9’s)
    - “4” purity $\geq$99.9% (3-9’s)

History (Cont)

- Title 13 CCR Section 2292.7-1995
  (California Code of Regulations)

  - 1 grade
    - $\geq$ 98 % pure
    - $\geq$ 0.19% combined N_2, Ar, H_2O
    - $\geq$ 0.01% (100 ppm) Total Hydrocarbons
    - $\geq$ 2 ppm Sulfur
    - Assumes balance is He, CO and CO_2

History (Cont)

- Title 13 CCR Section 2292.7 (Cont)
  - Current law has stricken this requirement
  - Confusion on requirement which replaced the original requirement.

    "Starting 1/1/95, the hydrogen fuel at ambient conditions must have a distinctive odor potent enough for its presence to be detected down to a concentration in air of not over 1/5 (one-fifth) of the lower limit of flammability. This requirement applies only to hydrogen which is introduced into the vehicle fuel storage system in gaseous form."

History (Cont)

- ISO 14687-1999
  - Gaseous phase (Type I) has three grades
    - Grade A - Title 13 CCR Section 2292.7-1995
    - Grade B – JIS K-0512 Type 3
    - Grade C - MIL-PRF-27201C
  - Liquid phase has one grade
    - Type II - MIL-PRF-27201C
  - Slush phase has one grade
    - Type III – (Undefined)

Issues

- The ISO document will not meet present and near term fuel cells and fuel storage media requirements.
- ISO 14687 specifies type I Grade A for “fuel cells for transportation”
- Purity is defined as:

100% - Σ Specific impurities tested for

Impurities and thresholds are specific to the grade

Note: it does not preclude impurities not tested for (e.g. Sodium, Lithium, Potassium, etc.)

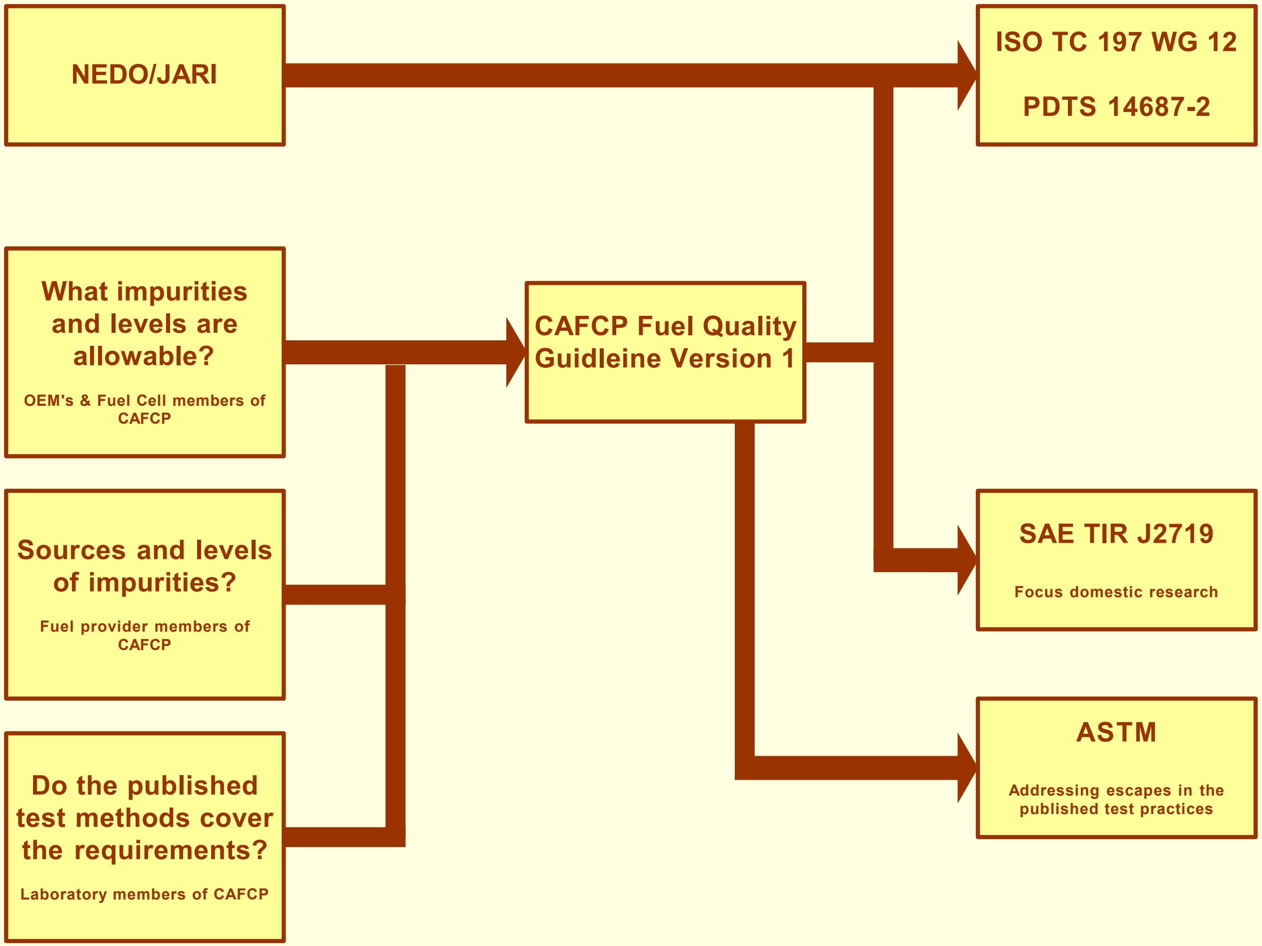
Activities

- NEDO/JARI initiated correction to ISO
  - Removal from original standard
  - Start of a technical specification
- US industry becomes involved
  - API
  - ASTM
  - CGA
  - NHA
  - SAE
  - USFCC
  - etc.

Activities (Cont)

- Issues are:
  - What impurities and levels are allowable?
  - Sources and levels of impurities?
  - Do the published test methods cover the requirements?
  - Can a cost effective fuel be generated?

Activities (Cont)



Contents of TIR

Species	On FC Stack	On BOP	On Storage
Inert gasses (Helium, Argon, Nitrogen)	H_2 dilution effect only	May affect purging rate and blowers	Believed to affect cycle life of MeH
Hydrocarbons	Aromatics, acids, aldehydes, etc. degrade performance	Unknown	May to affect cycle life of MeH
Oxygen	Tolerant to > 500 ppm	May form ice	Believed to affect cycle life of MeH
Carbon Monoxide	Reacts, degrades performance (reversible?)	No effect	Believed to affect cycle life of MeH
Carbon Dioxide	Tolerant at 100 ppm – limited CO back shifting	No effect	Believed to affect cycle life of MeH

Contents of TIR (Cont)

Species	On FC Stack	On BOP	On Storage
Formaldehyde	Reacts, lost performance (reversible?)	Unknown	Unknown
Formic Acid	Reacts, lost performance (reversible?)	Unknown	Unknown
Sulfur Compounds	Reacts, lost performance (irreversible!!!)	Unknown	Unknown
Ammonia	Degrades membrane ionomer conductivity	Unknown	Unknown
Water	Tolerant to > 500 ppm	Ice adversely affects control components	Affects cycle life of MeH

Contents of TIR (Cont)

Species	On FC Stack	On BOP	On Storage
Sodium	Degrades membrane ionomer conductivity	May adversely affects control components	Unknown
Potassium	Degrades membrane ionomer conductivity	May adversely affects control components	Unknown
Halogenated Compounds	Reacts, lost performance (irreversible!!!)	Unknown	Unknown
Particulates	May degrade membrane	Adversely affects control components	Unknown

Intended use of TIR

It is envisioned that the TIR document will be used to:

- Simplify the testing and documentation requirements for fueling stations used in the fleet demonstration programs
- Prioritize the testing of the effects of non-hydrogen constituents on fuel cell and storage media performance
- Prioritize the durability effort on fuel cells
- Prioritize the development of analytical measurement techniques and instruments
- Assist in the compatibility testing of materials to be used with hydrogen fuel
- Assist in setting the minimum functional requirements for components to be in contact with hydrogen fuel
- Continue the dialogue in generating a fuel specification

Intended use of TIR (Cont)

- The fuel cell industry has voiced concern and has limited data on :
  - Alcohols
  - Aldehydes
  - Organic acids
  - Aromatics
  - Diols (glycol)

- The fuel cell industry has limited data on:
  - Alkanes
  - Alkenes
  - Cyclo- forms

- The fuel cell industry believes moderate concentrations of methane are acceptable. Long term testing results are absent.

- The fuel cell industry has limited data on the effect of contaminants under conditions such as driving cycle, start/stop, freeze start, fuel recirculation, etc.

Intended use of TIR (Cont)

- The fuel providers would like to have following compounds investigated by the fuel cell and fuel storage industries first:
  - Argon
  - Carbon Dioxide
  - Carbon Monoxide
  - Helium
  - Methane
  - Nitrogen

Progression to Standard

- Areas of present activity
- Proposed schedule
- Areas of interaction

Progression to Standard

Areas of present activity

- Fuel Cell Testing
  - USFCC has generated a series of documents supporting the testing of the effects of impurities on testing
  - OEM's and Fuel providers have requested DOE fund the testing
  - JARI, LANL, HNEI are presently conducting testing from other funding sources.

Progression to Standard

Areas of present activity (cont)

- Containment and Storage Testing
  - OEM's and Fuel providers have requested DOE testing include likely contaminants on:
    - Metals
    - Composites
    - Plastics
    - Storage media

Progression to Standard

Areas of present activity (cont)

- ASTM (D-03 committee) is revising published test methods
  - D1945-03 Standard Test Method for Analysis of Natural Gas by Gas Chromatography
  - D1946-90(2000) Standard Practice for Analysis of Reformed Gas by Gas Chromatography

Progression to Standard
Areas of present activity (cont)

- ASTM (D-03 committee) is generating new published test methods
  - D1945-03 Standard Test Method for Analysis of Natural Gas by Gas Chromatography
  - D1946-90(2000) Standard Practice for Analysis of Reformed Gas by Gas Chromatography
  - WK4548 Standard Test Method for Determination of Trace Contaminants in Hydrogen and Related Fuel Cell Feed Gases (GC/MS Method)

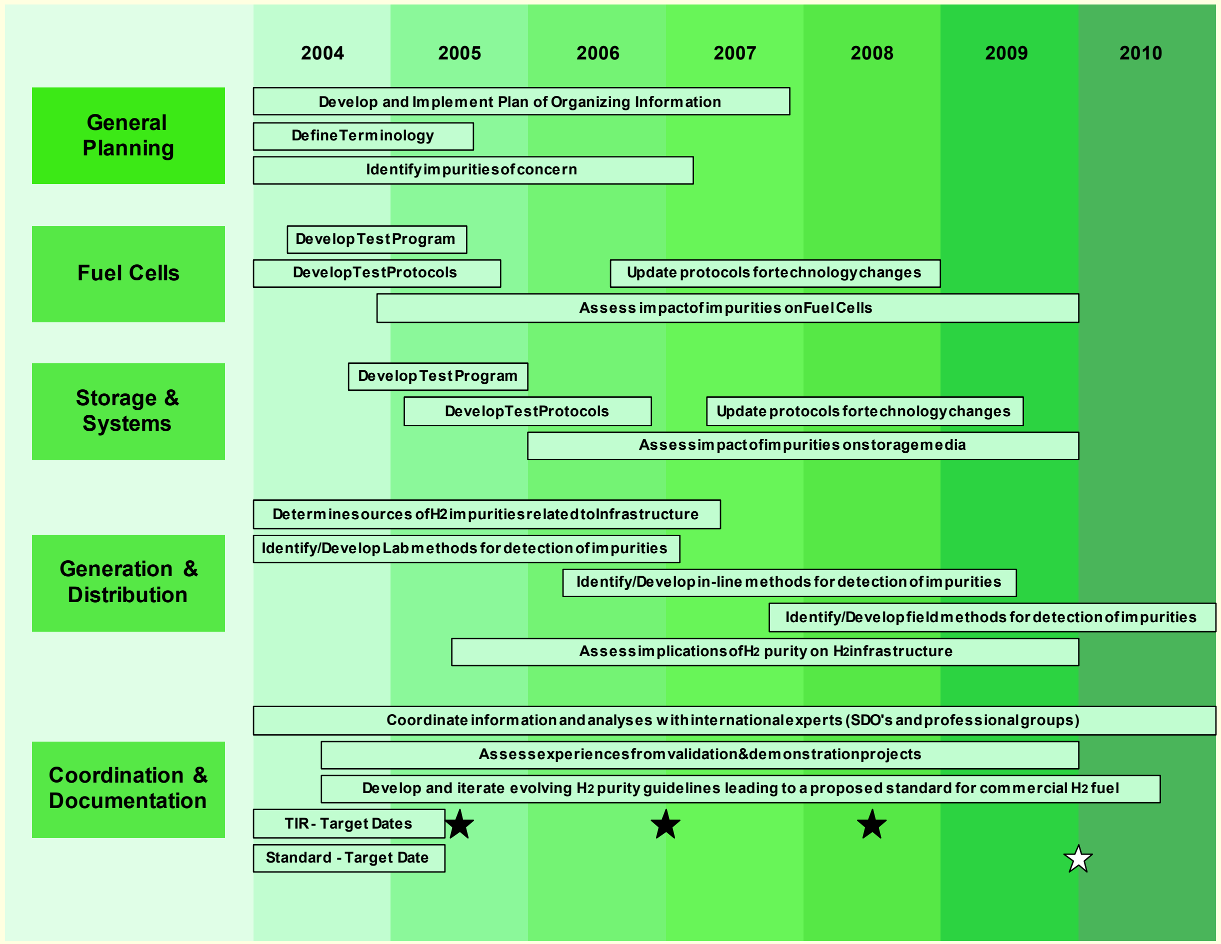
Progression to Standard

Areas of present activity (cont)

- WK5847 Standard Practice for Sampling of High Pressure Hydrogen and Related Fuel Cell Feed Gases
- WK6527 Standard Test Method for Ion Selective Electrode (ISE) or Ion Chromatography Based Determination of Ammonia in Hydrogen and Other Fuel Cell Feed Gases
- WK6624 Standard Test Method for Determination of Formaldehyde and Other Carbonyl Compounds in Hydrogen and Other Fuel Cell Feed Gases
- WK8150 Standard Test Method for Determination of Ammonia in Hydrogen and Other Gaseous Fuels by Gas Chromatography and Nitrogen Chemiluminescence Detection
- WK7610 Standard Specification for Hydrogen Thermophysical Property Tables

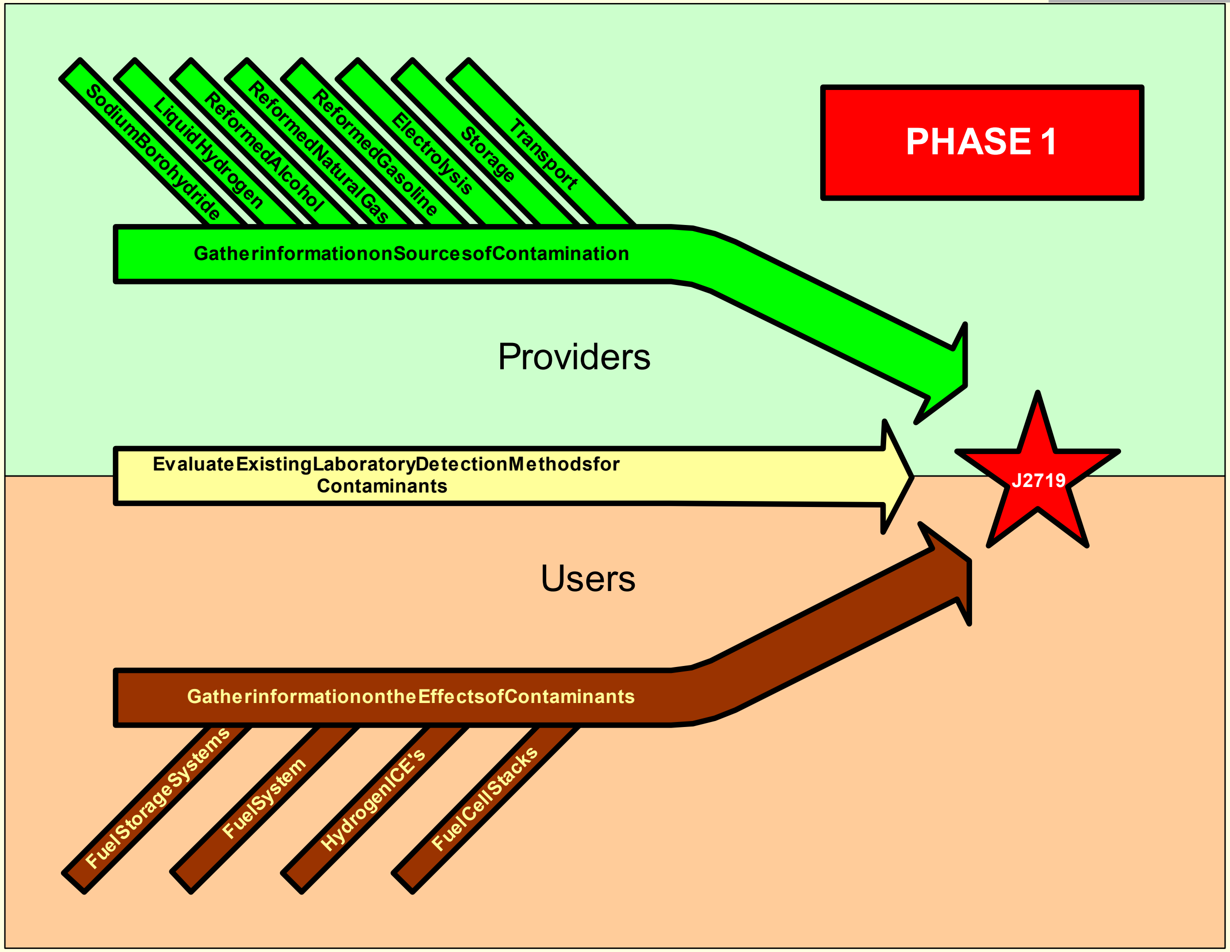
Progression to Standard

Proposed schedule



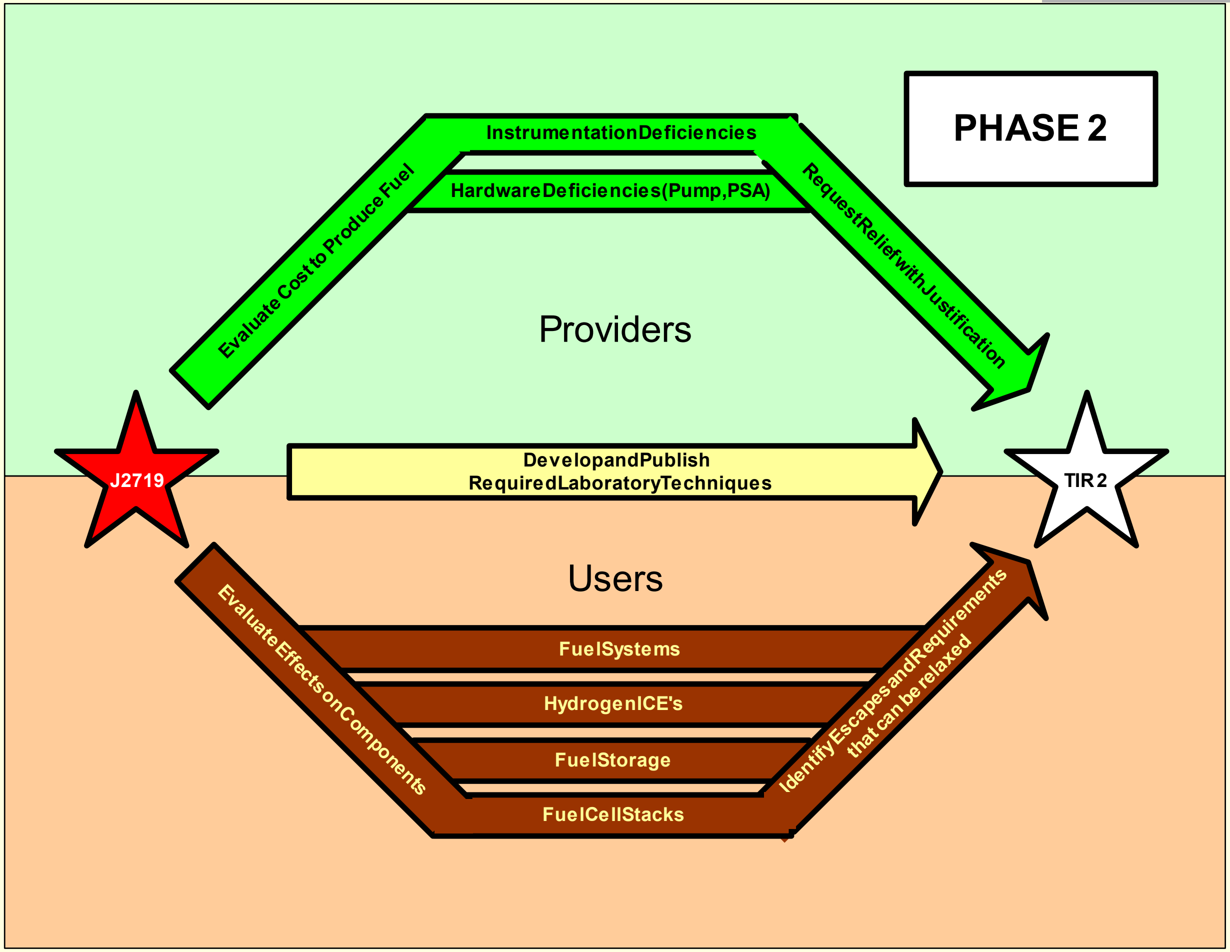
Progression to Standard

Areas of interaction



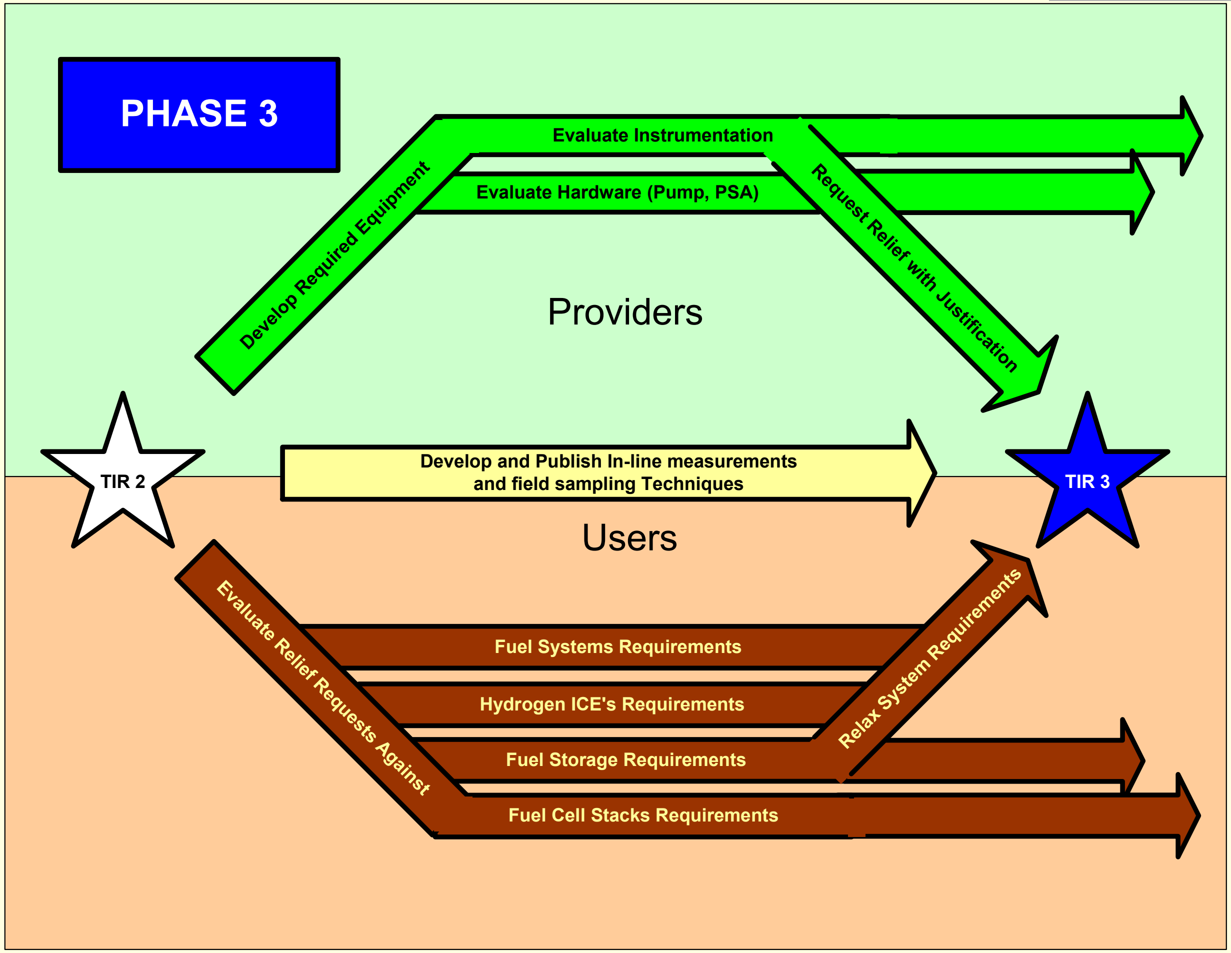
Progression to Standard

Areas of interaction (cont)



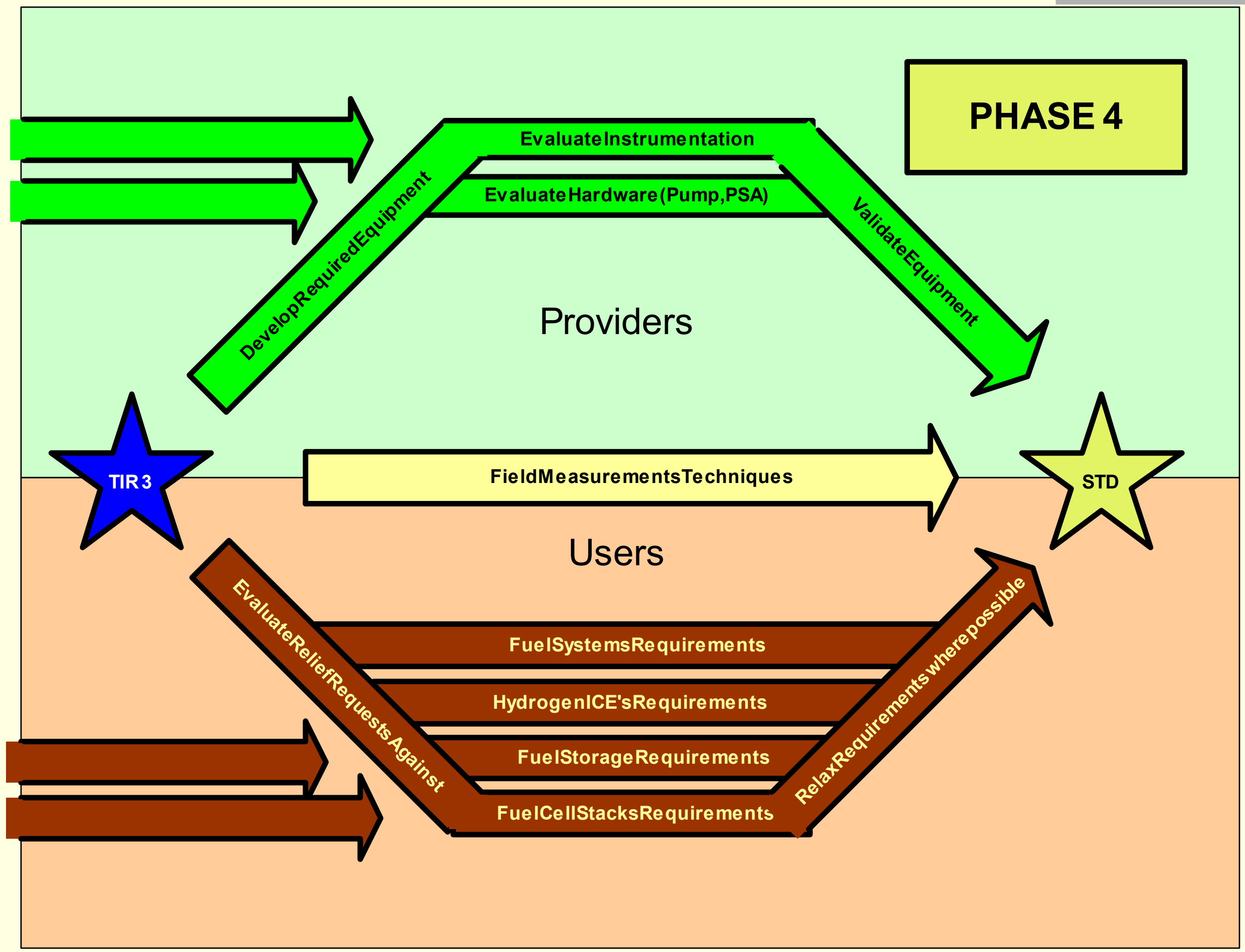
Progression to Standard

Areas of interaction (cont)



Progression to Standard

Areas of interaction (cont)



Progression to Standard

Summary

- Most of the ground work is set
- Testing and planning needs to be flexible
- Stake holders are presently working together
- A lot of work to be done
- Communications between stake holders is key