

March 2018

ELECTROPLATING INNOVATIONS FROM HONEYWELL

Honeywell
THE POWER OF **CONNECTED**

Presenters

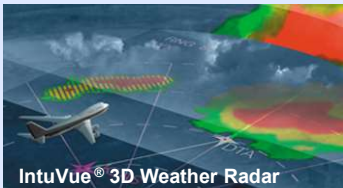
- Dr. Ersan Ilgar
- James Piascik
- Andrea Julio
- David Davitt
- Jeff Olney
- Dr. Prashant S. Chintawar (Prashant.Chintawar@Honeywell.com)

Honeywell Overview

\$38.6B Global Industrial Company, Segment Margin of 18.8%
~53% of Sales Outside U.S.

Aerospace

\$15.2B
Sales



IntuVue® 3D Weather Radar

Unmatched Scope of Offerings

- Mechanical, Cockpit, and Software Offerings From Nose to Tail
- Apps, Services, Maintenance, Subscriptions
- End-to-End Connectivity Solutions From Hardware to Airtime
- Turbochargers for Fuel Efficiency

Performance Materials and Technologies

\$9.5B
Sales



Experion® Orion Console

Winning Technology

- Refining and Petrochemical Catalysts
- Gas Processing Modular Offerings
- Solstice® LGWP Materials
- SmartLine Transmitters
- Asset Optimization Software

Home and Building Technologies

\$9.2B
Sales



evohome

Connecting Homes and Buildings

- Security and Fire
- Connecting Homes With Lyric
- Open Software Connecting "Internet Of Things" in Buildings

Safety and Productivity Solutions

\$4.7B
Sales



Vocollect™

Connecting Workers

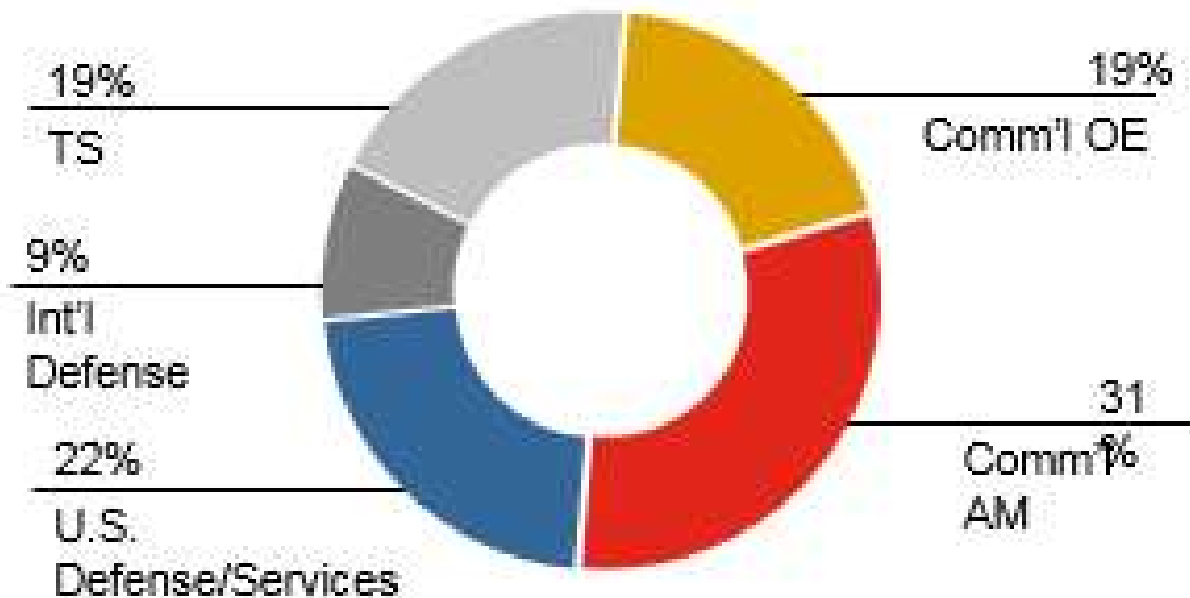
- Wireless, Voice, Mobility, Data Analytic Solutions for Workers
- Warehouse Automation
- Keeping Workers Safe

Reflects 2015 Full Year Results

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Aerospace Business Breakdown

Business Mix



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Revenue - \$15.2B in 2015

Technology & Innovation

22,000
technologists
worldwide

97
research &
engineering
facilities

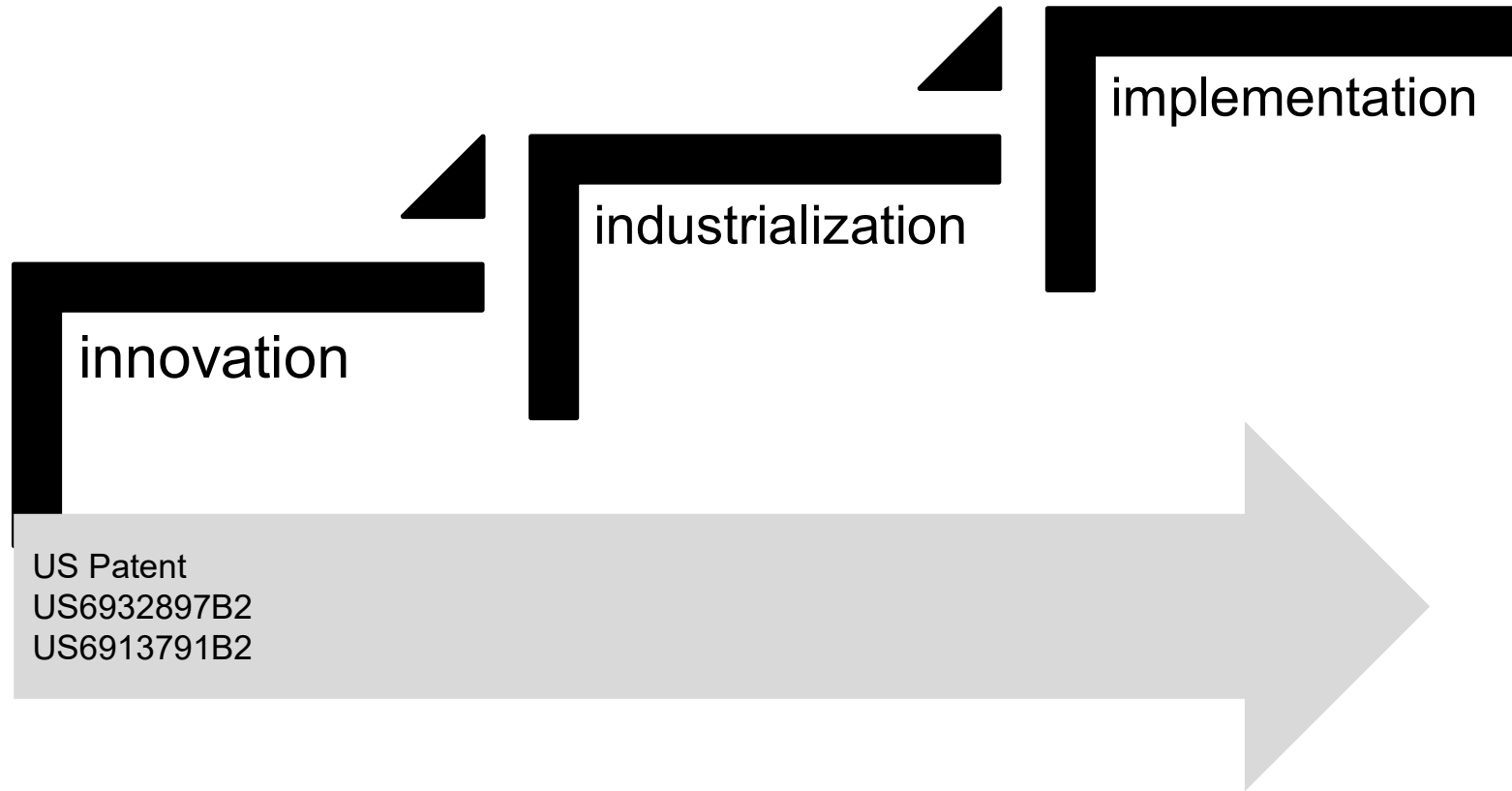
32,000
patents granted
or pending

4,790
Aerospace patents
granted or pending

Developing
solutions for the
world's toughest
challenges



20+ Years of Track Record in Electroplating

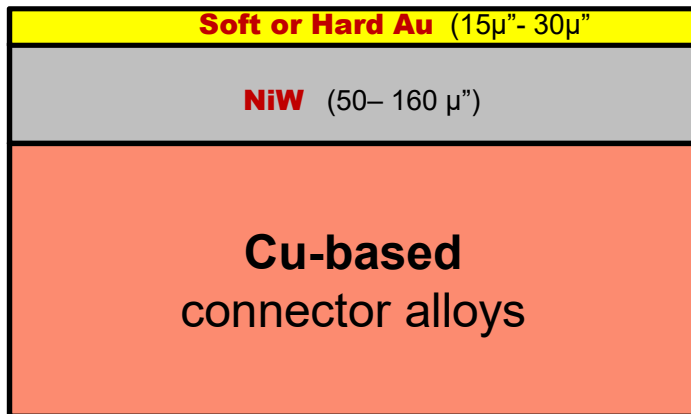


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We use these coatings in demanding space applications

Connector Technology

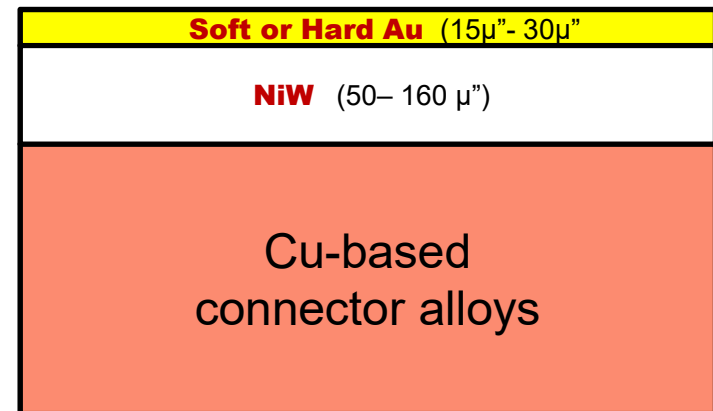
Current Connectors



ISSUES with Ni LAYER

- **LOW HARDNESS-** Typical under layer nickel hardness is (HV=150-300) which may not be hard enough to support the thin gold (Au) film under wear conditions.
- **Ni Diffuses into Au** - Although Ni is used as barrier coating to inhibit diffusion of Cu and/or Zn into Au where they could oxidize (tarnish) and form insulating corrosion product on the surface. However, nickel itself can also diffuse into the Au and may form an insulating film of NiO as a corrosion product. At very high temperatures and longer exposure times, nickel based the gray-greenish patina may be observed on Au surfaces indicating the Ni-diffusion to the Au surface,.

Honeywell NiW Based Connectors



HONEYWELL SOLUTION – NiW Based Barrier Layer

- **HIGH HARDNESS-** NiW under layer is harder (HV=600-800) compared pure Ni and will support the gold layer to provide better wear resistance which will increase durability, In addition, high temperature conditions further increases the hardness the NiW.
- **MORE EFFECTIVE DIFFUSION BARRIER** - NiW does not diffuse as readily as pure Ni because of high melting point NiW intermetallic compound (W atom is very large to move). Auger Electron Spectroscopy (AES) surface analysis showed that thermally treated connectors showed significantly less Ni on the Au surface with NiW under layer coating compared to pure Ni.

Interconnect Diffusion Barrier Plating

Plating Parameters

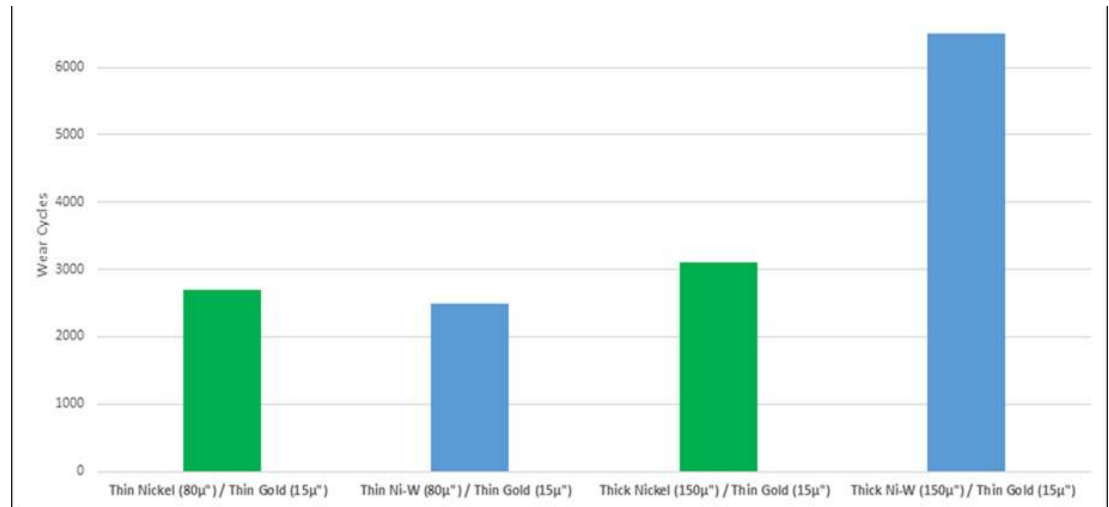
Substrate: 1 "x 3" Oxygen Free Copper (OFC)

Ni-Coating (Control) = 80 μ " and 150 μ "

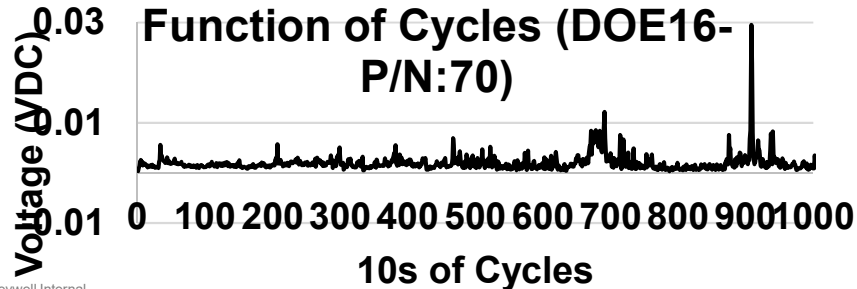
NiW Coating = 80 μ " and 150 μ "

Hard Au Coating = 15 μ " and 30 μ "

- Sliding Contact Wear
- Thermal Oxidation
- Contact Resistance (as-is, after wear, thermal exposure and corrosive gases)



Contact Wear Resistance as a Function of Cycles (DOE16-P/N:70)



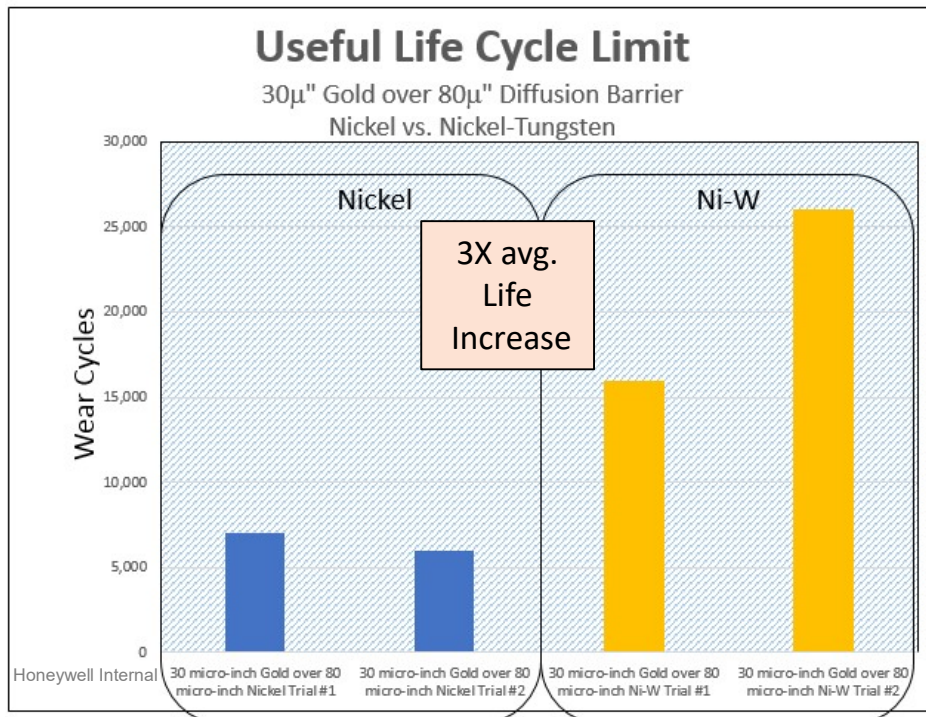
Honeywell Internal

Gold Reduction in Connectors

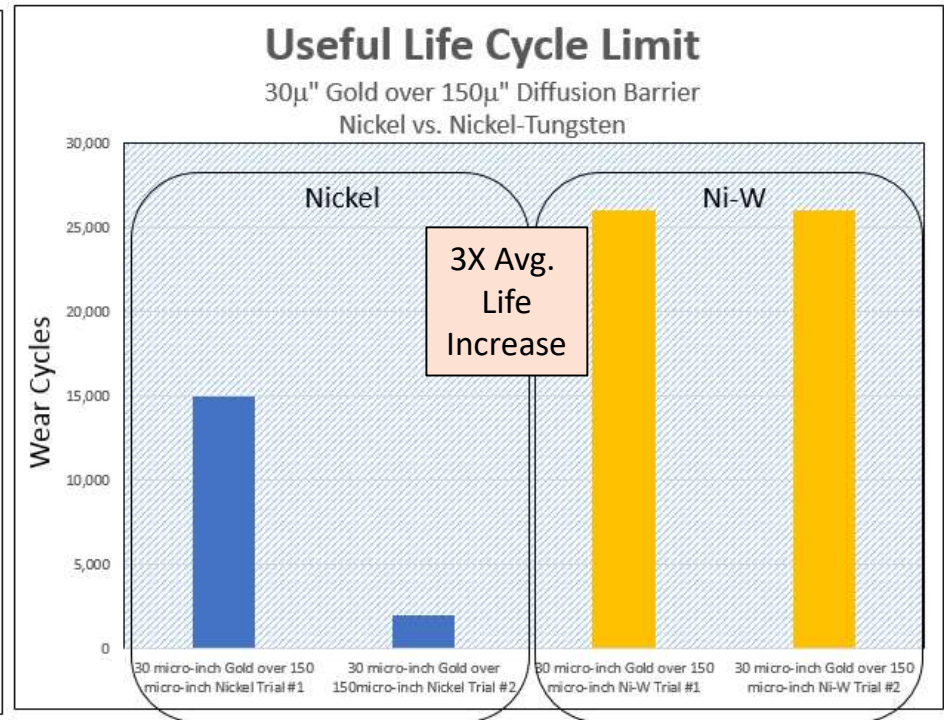
Contact Wear Testing – Thick Gold

- With thick gold (30 micro-inches) Ni-W significantly out-performs Nickel.
- We believe it may be linked to substrate surface finish.

Thick Gold / Thin Barrier



Thick Gold / Thick Barrier



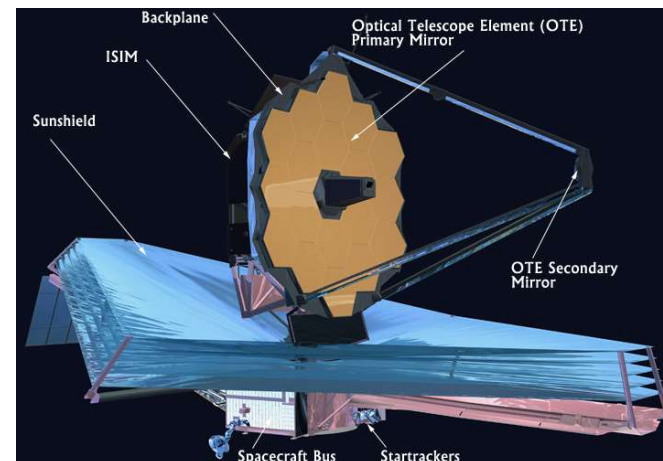
COM DEV Legacy

- 40 years history as satellite communications payload supplier
- Hardware on >85% of all satellites flying today (Over 750 spacecraft)
- Joined Honeywell: Feb 2016
- Part of Electronic Solutions / Space
- Located in Cambridge, Ontario, Canada



Products

- RF/microwave components
- Multiplexers, waveguides, filters
- Switches (RF, coax)
- Avionics / satellite receivers
- Specialty payloads
 - Optics, AIS (ship tracking)
 - James Webb space telescope
 - Smallsats / microsats



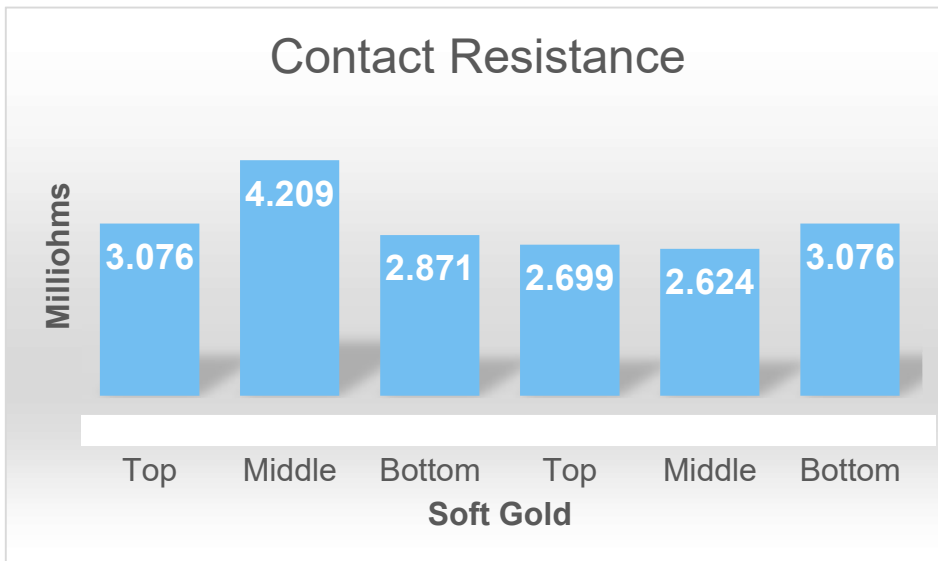
Summary of Qualified Processes

Process	Substrate
Electrolytic Gold Plating (Soft and Hard Gold) Typical Thicknesses: 50 μ" to 400 μ"	Oxygen Free Copper, Beryllium Copper, Brass, Invar 36, Invar 32-5, Kovar, Netic, Carpenter 49, Thermkon, Paliney, Aluminum
High Phosphorus Electroless Nickel Thicknesses 50 μ" to 1000 μ"	6061 Aluminum, 7075 Aluminum, Beryllium Copper, Oxygen Free Copper, Brass, Stainless Steel, Hiperco, Kovar, Netic, Carpenter 49, Invar 32-5, Invar 36, R3100
Electrolytic Nickel Typical Thicknesses: 50 μ" to 300 μ"	Titanium, Beryllium Copper, Invar 32-5, Invar 36, Stainless Steel
Electrolytic Copper and Silver Typical Thicknesses: 100 μ" to 1000 μ"	Invar 36, Invar 32-5, Netic, R3100, Kovar, TC-31, Aluminum Oxygen Free Copper, Beryllium Copper, Brass, Stainless Steel, Titanium
Chemical Conversion Coating Class 1A and Class 3	6061 Aluminum, 7075 Aluminum
Passivation Type 2 and Type 6	Type 2: stainless steel alloys containing 12-14% Cr, or alloys with greater than 0.15% sulfur or selenium Type 6: Austenitic 200 and 300 series chromium nickel alloys and chromium grades with greater than 17% Cr composition,
Cleaning Processes	Aluminum, Stainless Steel, Nickel, Invar, Kovar, Copper, Cobalt, Hiperco 50, Nickel, Copper, Gold, and Silver Plated Coatings, Non porous loads, garnets, ferrites, quartz, fluoroloy, boron nitride, corderite, RS4200CHP

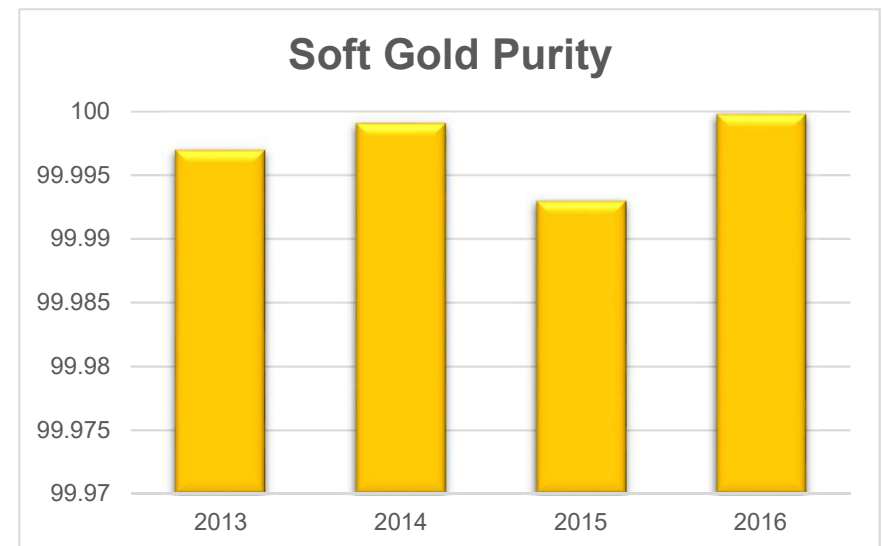
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Potential New Substrates – Mo, W, Mg, Pt/Au

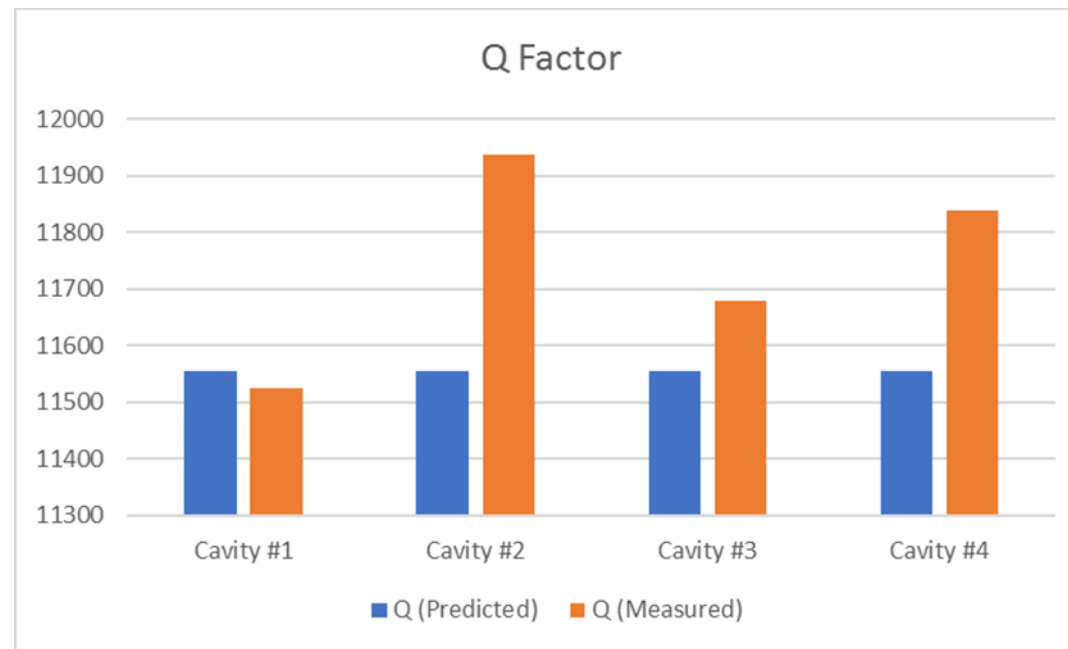
Our Differentiators - Low Contact Resistance & Au Purity



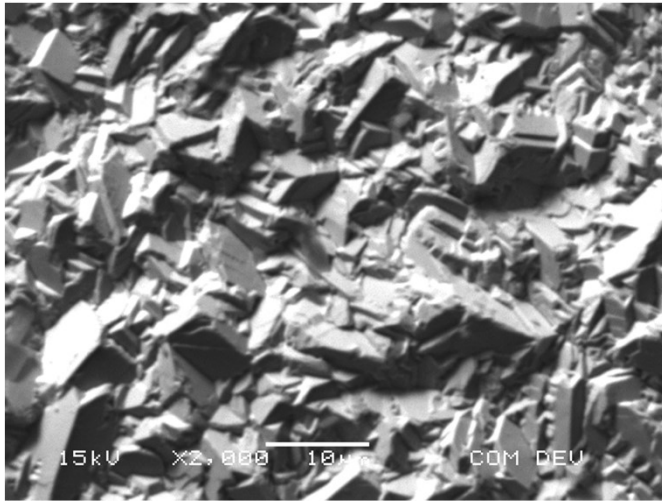
Contact Resistance Test
Reference: ASTM B539-02,
ASTM B667-97



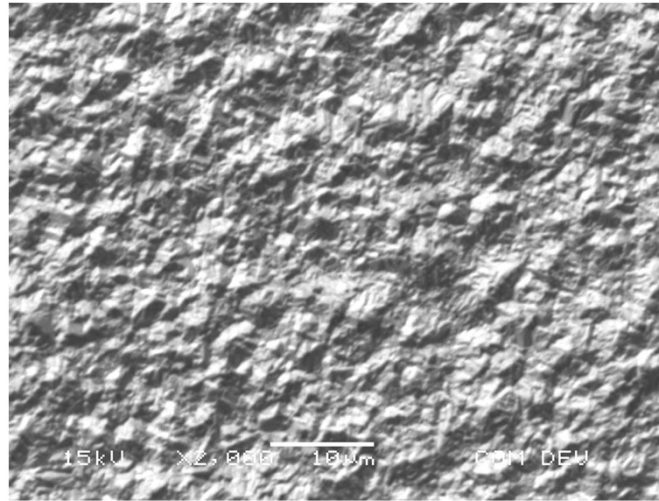
Our Differentiator – High Q Factor



Our Differentiator - Ag Plating Grain Structure

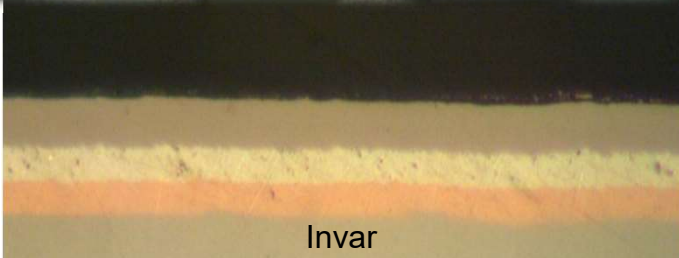
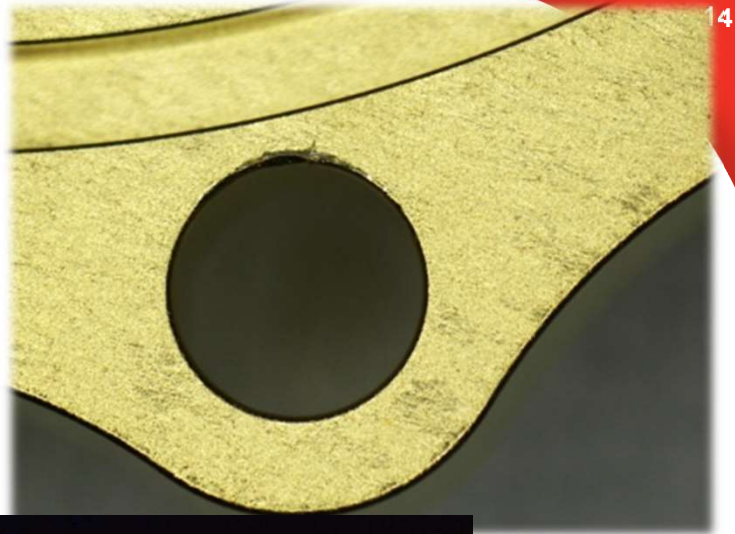


Conventional DC Silver Plate
Surface Finish (2000x)

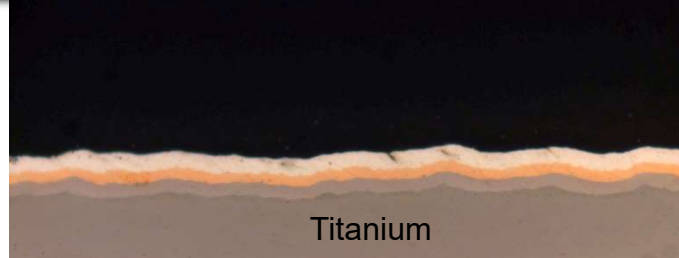


Honeywell Silver Plate
Surface Finish (2000x)

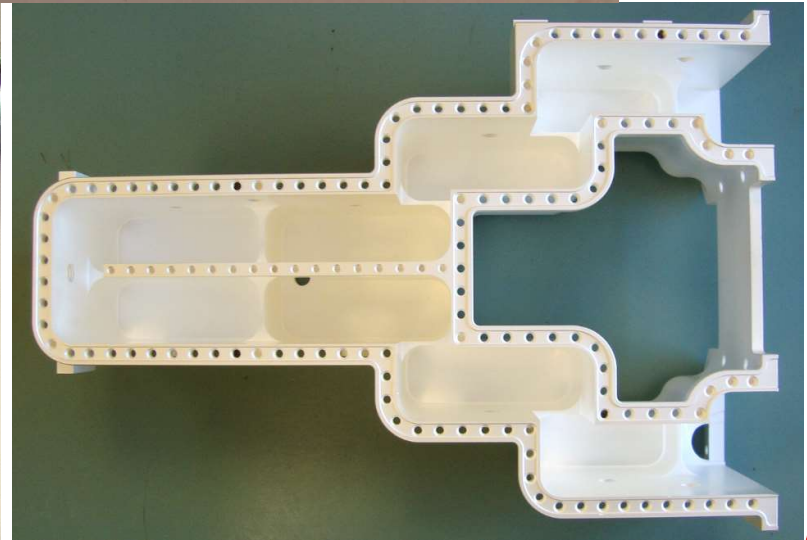
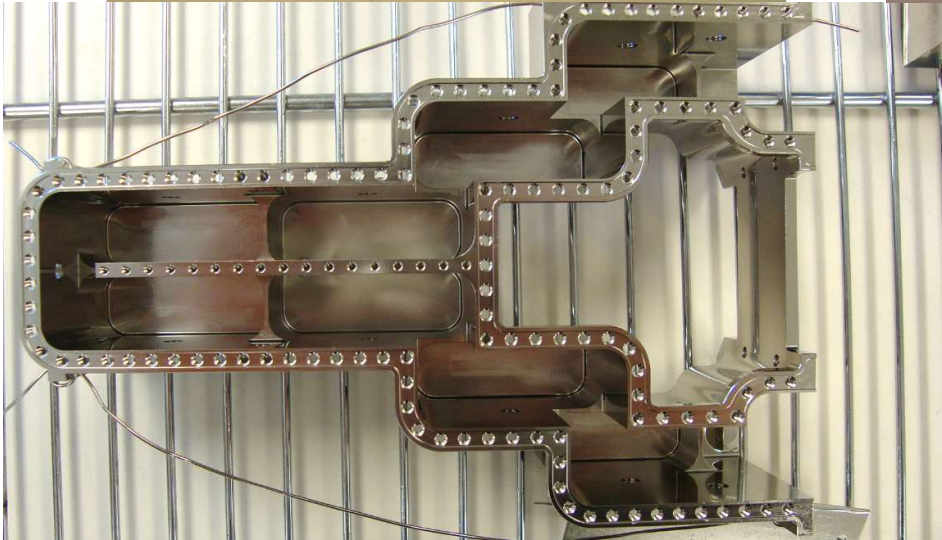
As shown by the SEM photomicrographs, conventional DC plating produces a larger, more defined grain size and clearly crystalline shape. The plating process used by Honeywell produces a nearly amorphous structure that is much more compact, and with less defined grain boundaries.



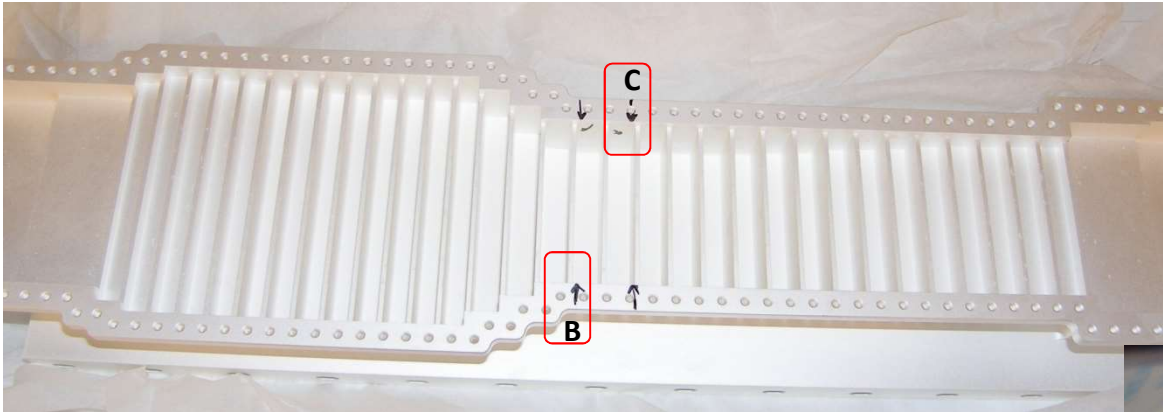
Invar



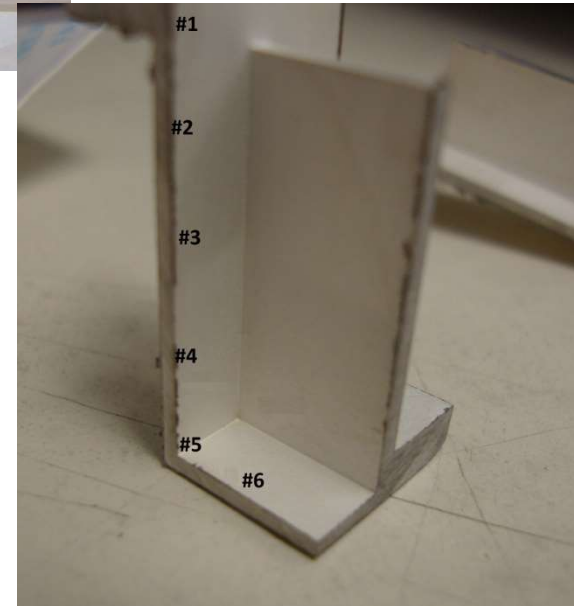
Titanium



Uniform Plating Coverage

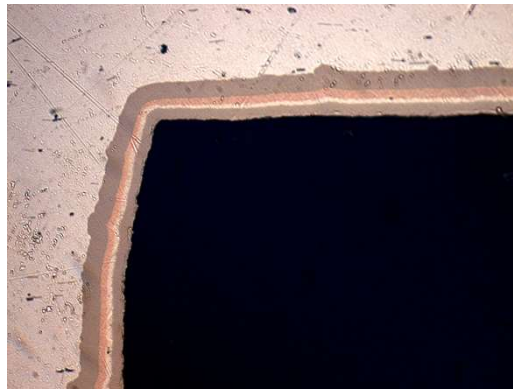
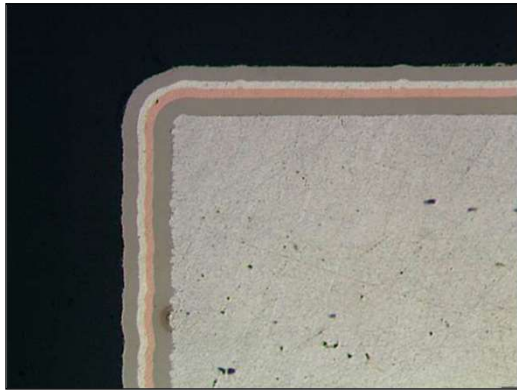


Silver Plated Filter

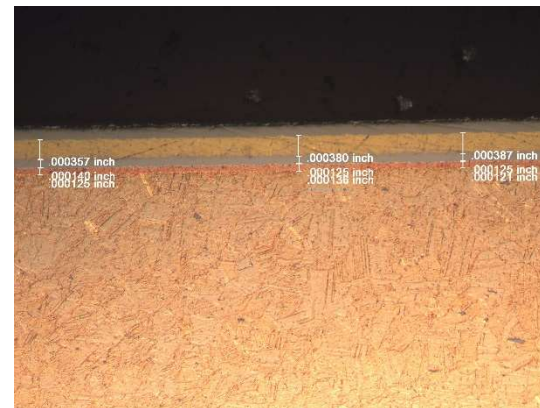
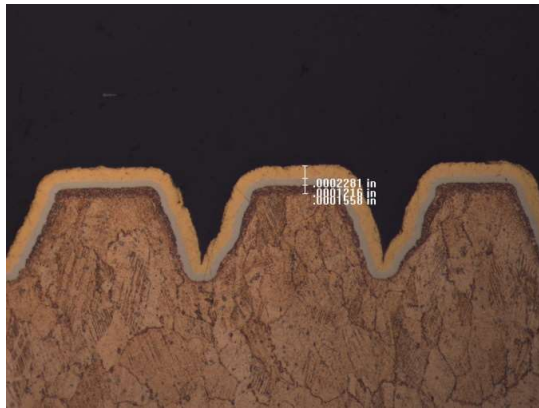


Robust process allows plating coverage around small complex geometries.

Plating Coverage



Nickel/Copper/Silver Plating



Copper/Nickel/Gold Plating

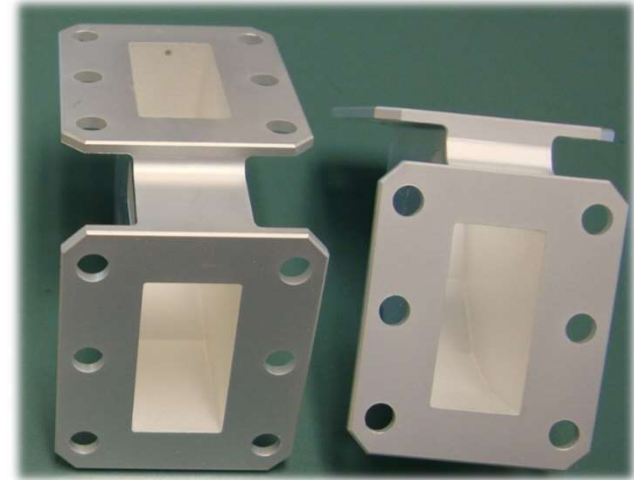
Capability Highlights

- **Silver**

- RF-critical hardware is silver plated
- Provides industry-leading RF quality with low loss and high-Q performance
 - provides excellent thermal properties
- Touch-screen power supply controllers with current manipulating capabilities
- Internal anodes can be used
- Six Cu and six Ag tanks

- **Gold**

- EEE components, RF switch components, anything where contact-resistance is critical
- Four tanks, hard and soft gold



Substrates

- Aluminum (6061, 7075)
- BeCu, Cu
- Invar & other Fe Alloys
- Titanium
- Stainless

Capability Highlights

- **Electrolytic Ni**
 - Titanium plating capable (patented)
- **Electroless Ni**
 - Automated controller for chemistry analysis and additions
 - Four tanks
- **Chromate conversion coating**
 - Alodine 1200S
- **Passivation**
- **Etching**
- **Cleaning**

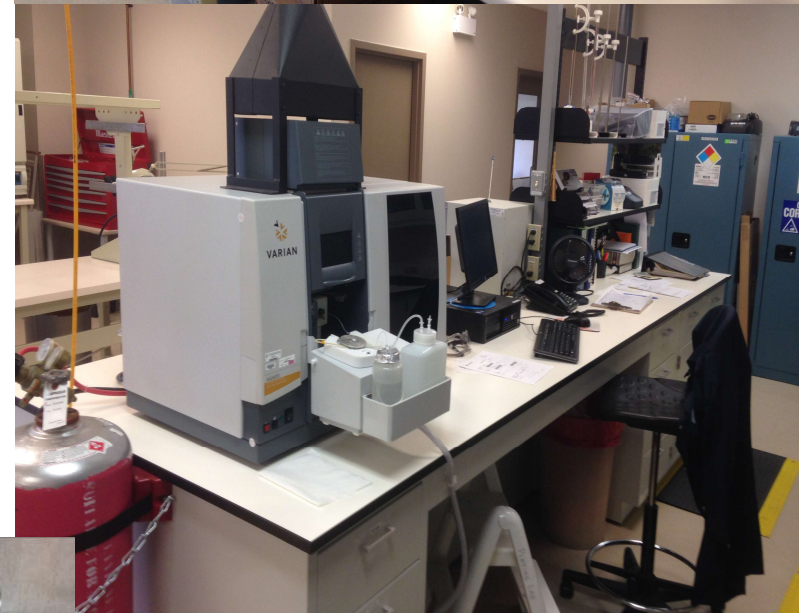


Cu-Ag Plating Line



Quality

- First pass yield >95%
 - Hardware is visually inspected in plating QC area (x2 – x40 Mag)
 - XRF for layer thickness measurements
- Wet-chemical lab
 - Atomic absorption spectroscopy for metals analysis
 - All bath analysis performed in-house
- Materials Testing Lab
 - SEM/EDX, micro-sections, thermal and humidity testing, hardness, etc.
 - Bend Test



Certifications

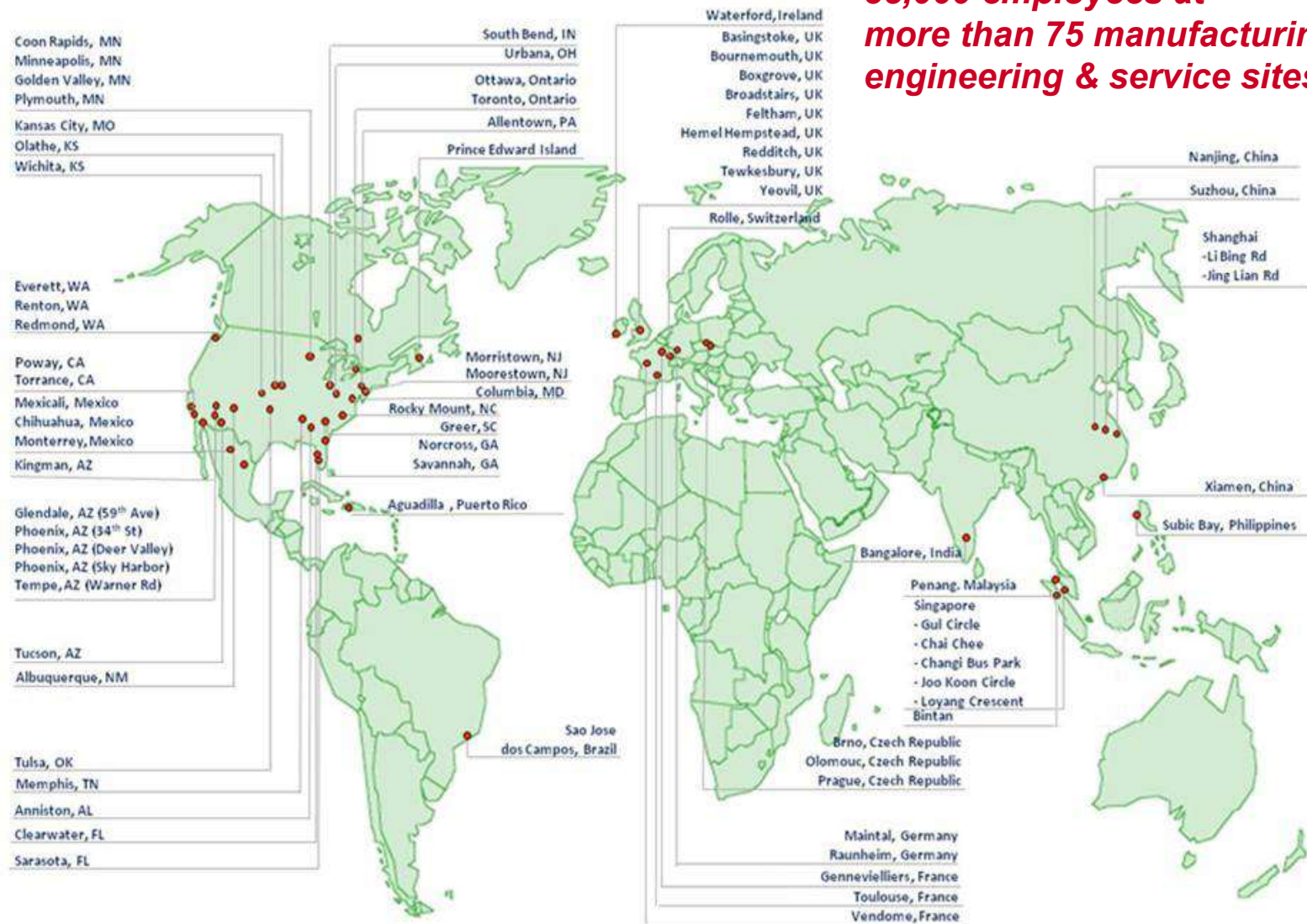
- ISO 9001:2015 and AS9100D
- Plan to be NADCAP Certified by 2019

- Plating Qualification
 - Qualification testing is performed to show compliance to the nearest applicable industry standard (MIL, AMS, ASTM, etc.), and is customized to include environmental factors applicable for space use.

 - Examples of test performed include plating thickness, adhesion test, appearance, humidity test, thermal cycling, microsection, SEM/EDX, electrical resistivity test, high temperature exposure, paint adhesion test.

Aerospace Global Footprint

38,000 employees at more than 75 manufacturing, engineering & service sites.



Summary

- Over 20 years of track record in innovation, production, and use of electroplating in demanding space and defense applications.
- Broad, proven, and high quality electroplating (some patented). Ability to plate proprietary chemistries as needed.
- Flexible production plant
- Global production, R&D, and tech support footprint