3M Science. Applied to Life.™

3M cover films for satellite solar cell arrays

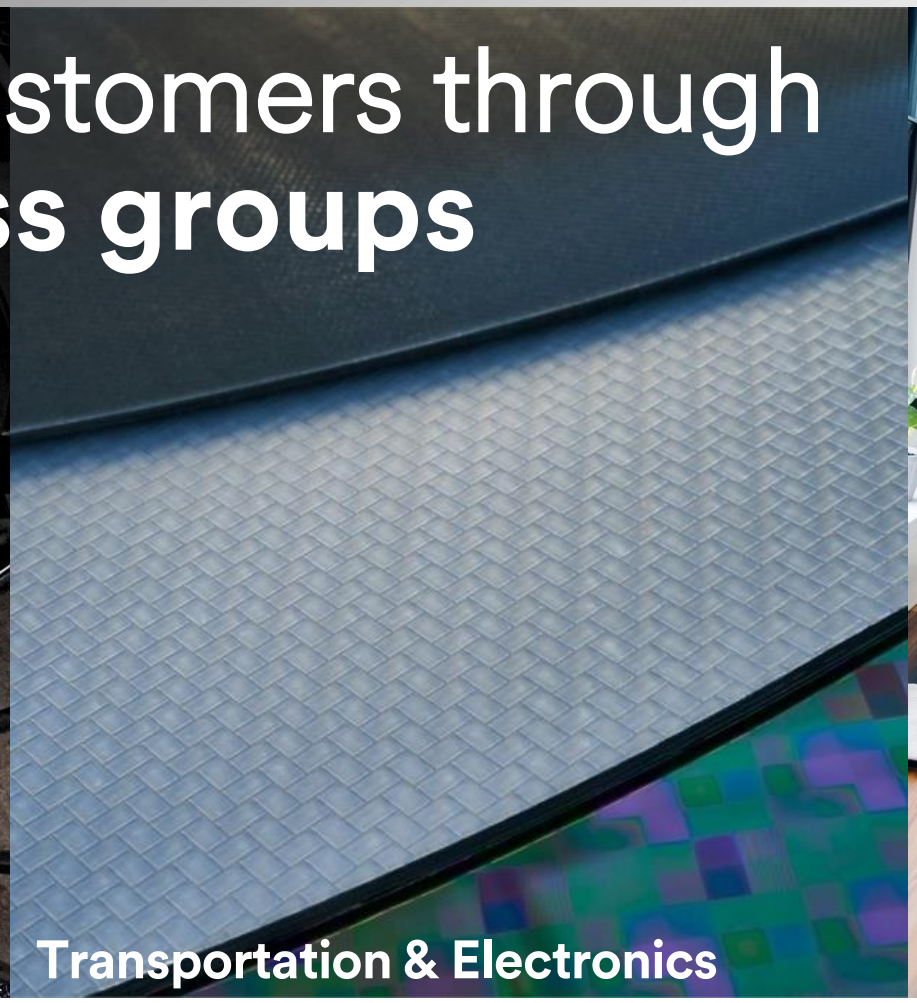
Gabe McAndrews

4/23/2026

Serving our customers through **three business groups**

Safety & Industrial

Transforming how work gets done



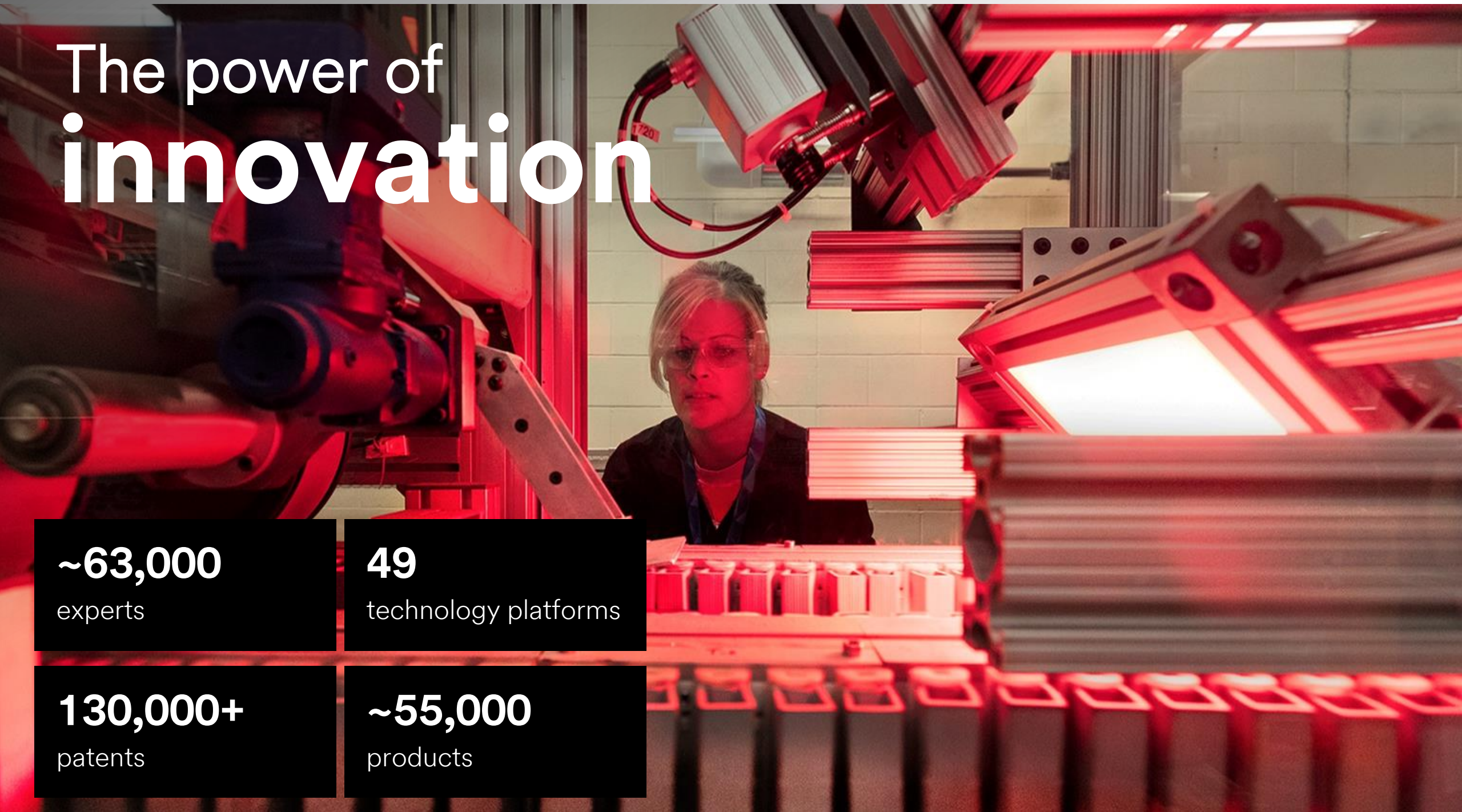
Transportation & Electronics

Solving tough customer challenges to advance a connected world

Consumer

Bringing 3M to the hearts and minds of consumers

The power of innovation



~63,000
experts

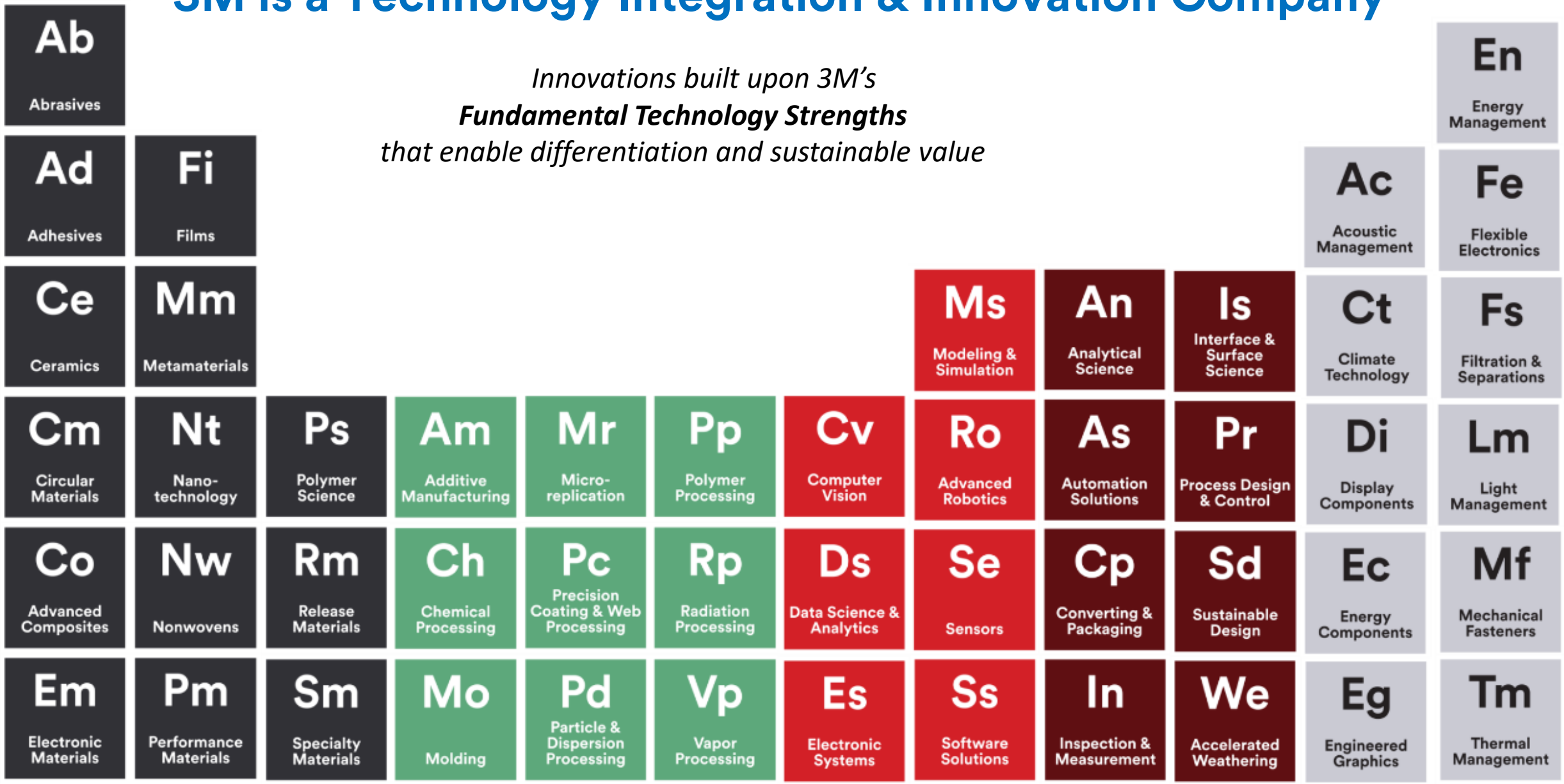
49
technology platforms

130,000+
patents

~55,000
products

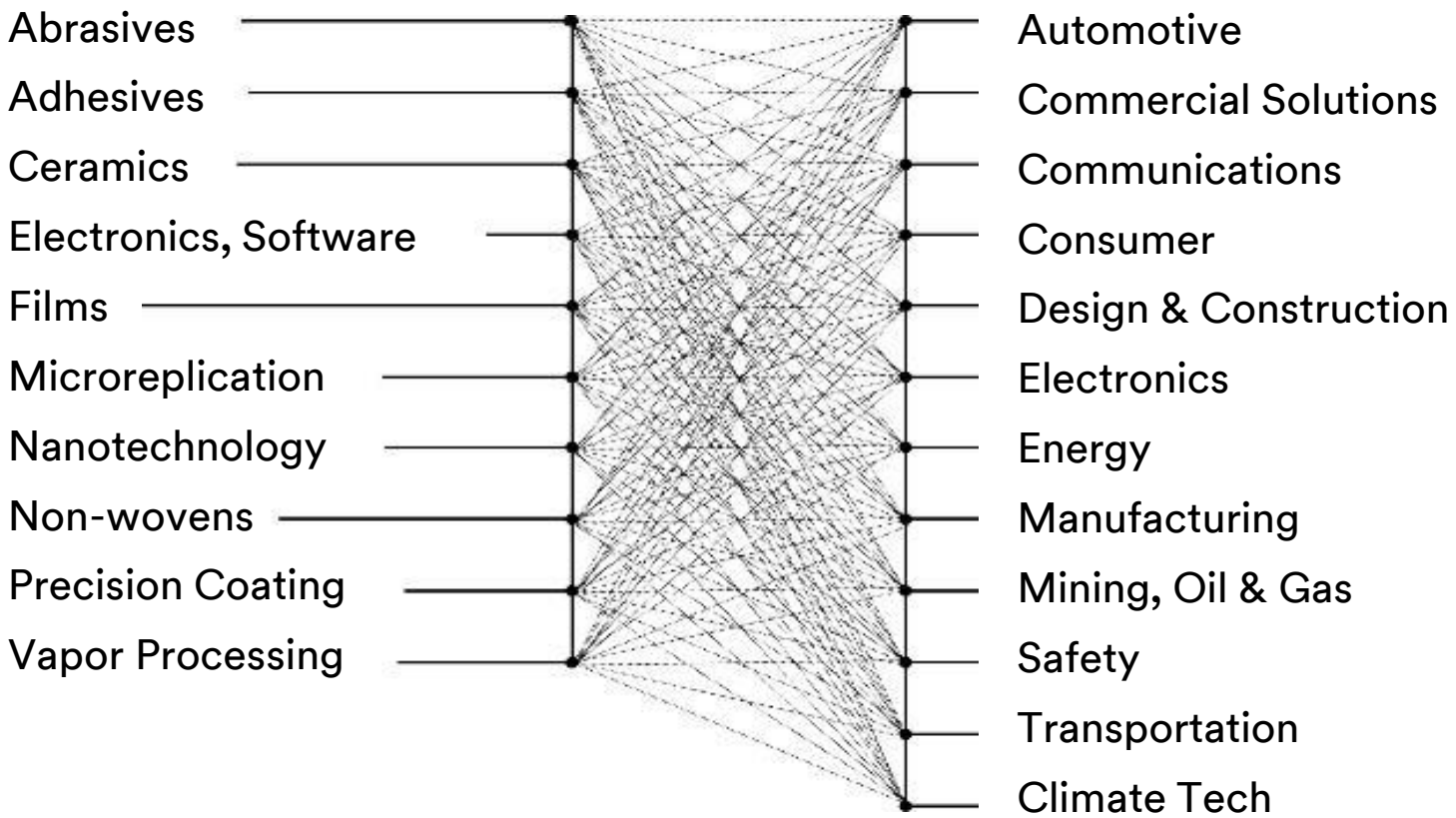
3M is a Technology Integration & Innovation Company

Innovations built upon 3M's
Fundamental Technology Strengths
that enable differentiation and sustainable value



Technology Platforms

Markets

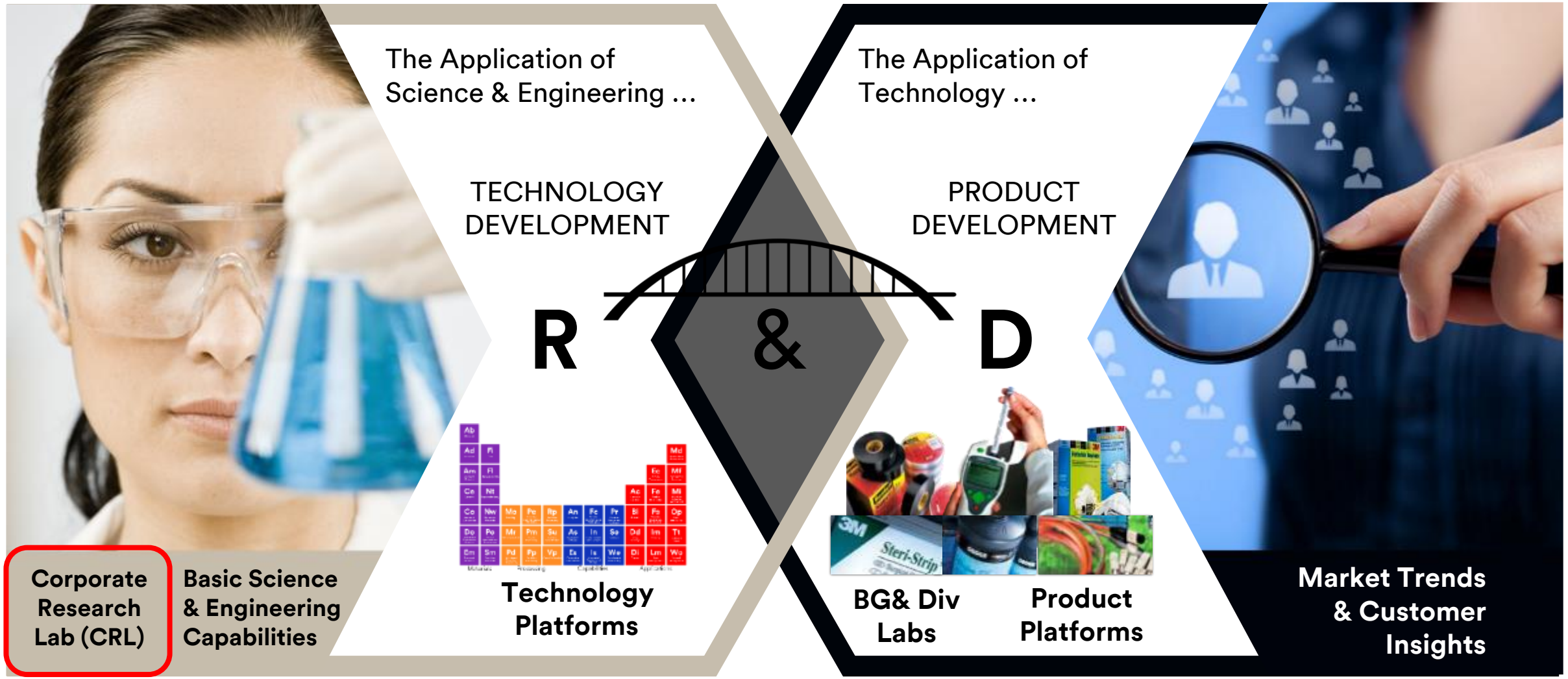


Making uncommon connections and innovating – that is what we do!

3M

3M operates an integrated innovation model

Creation and application of technology to product development



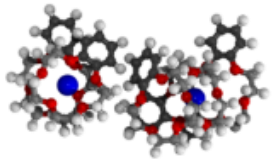
Commercialization through different go-to-market models: Consumer + Industrial + OEM Spec-in

CRL Integrates Analytical, Materials, Process, and Systems

Corporate Research Analytical Laboratory (CRAL)

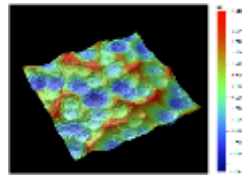
Growth through fundamental scientific understanding & data analytics

Molecular Analysis



Weathering Research Center

Materials Characterization



Imaging & Surface Analysis

Intellectual Property Substantiation

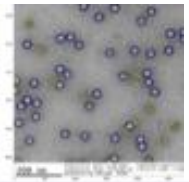
gALAxy Analytical Lab Analytics

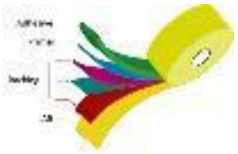
Analytical Analytics

Corporate Research Materials Laboratory (CRML)

Creating new materials that provide a sustainable competitive advantage

BioSciences



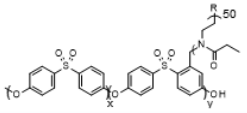


Adhesives & Release Materials

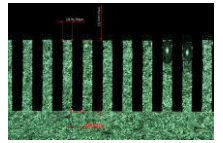
Optical / 5G

Ceramics & Glasses

Specialty Materials



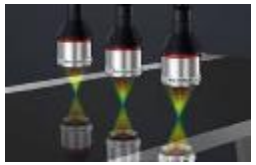
Films, fibers, coatings



Emerging Energy

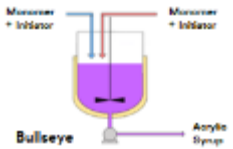
Corporate Research Process Laboratory (CRPL)

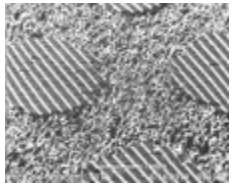
Building new, differentiated process and manufacturing platforms



Digital Manufacturing, Analytics & Processing

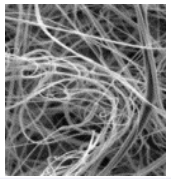
Materials & Radiation Processing

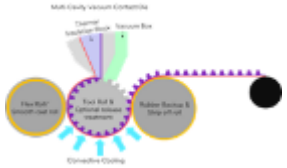




Precision Coating & Web Processing

Nonwovens, Membranes & Ultrasonics

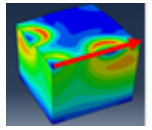




Specialty Films, Microreplication & Polymer Processing

Corporate Research Systems Laboratory (CRSL)

Building integrated systems and digital platforms to enable new products



Modeling & Simulation

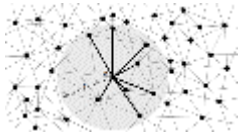
Software Technology, Machine Learning, & Data Science

Data Systems

Advanced Integrated Systems

AMX /Extreme Mechanics

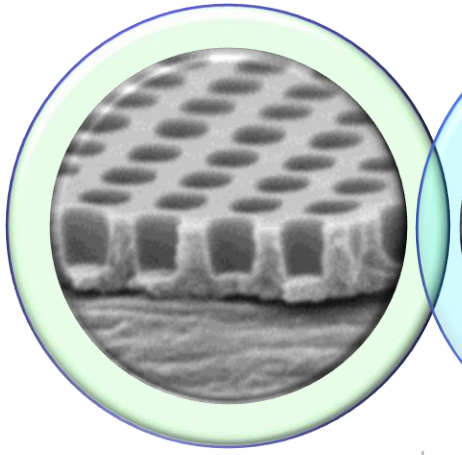
Materials Informatics



3M

Corporate Research Process Laboratory

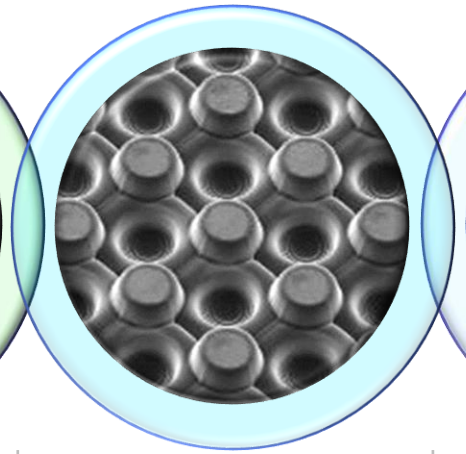
Precision Coating & Web Processing
PCWP



Technologies

- Coating
- Drying
- Printing & Patterning
- Optical Metamaterials
- Process Mechanics
- Embedded Modeling

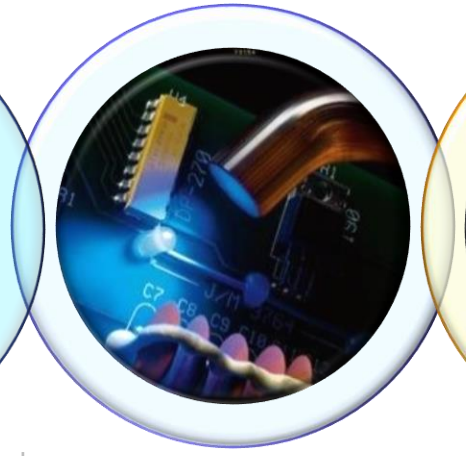
Specialty Films, Microreplication & Polymer Processing
SFMPP



Technologies

- Hot Melt Coating
- Reactive Extrusion
- Blown Film
- Oriented Film
- Extrusion Replication
- Continuous, Cast & Cure

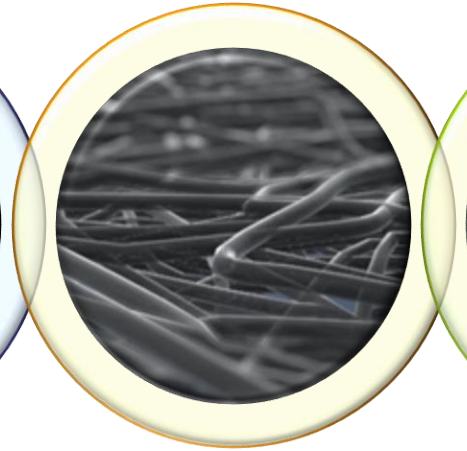
Materials & Radiation Processing
MRP



Technologies

- Chemical Processing
- Radiation Processing
- Plasma & Surface Modification
- Thin Films
- Ceramics & Particle Processing

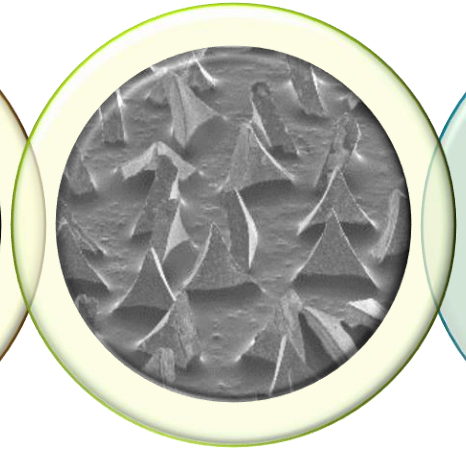
Nonwovens, Separations & Ultrasonics
NWSU



Technologies

- Melt Blown
- Spunbond
- Fiber Processing
- Separations Technologies
- Modeling & Informatics
- Ultrasonics

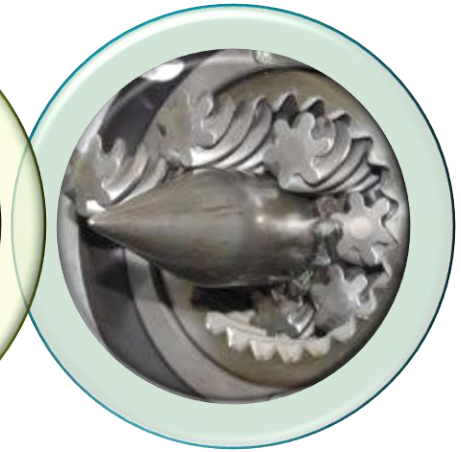
Digital Manufacturing Analytics & Processing
DMAP



Technologies

- High Resolution Additive Manufacturing
- Rapid Prototyping
- Injection Molding
- Measurement & Process Analytics
- Robotics & Automation
- Process Informatics

CRPL
EMEA



Technologies

- Euro Express Line
- Hotmelt, Film, Multilayer & Co-Extrusion
- Liquid Coating
- PSA Process Tech
- Reactive Extrusion
- Hotmelt Compounding
- Injection Molding

3M™ Ultra Barrier Solar Film

Typical Properties

Properties	Test Method	Typical Values*	Comment
Water Vapor Transmission Rate	Mocon, Aquatran	< 6×10^{-5} g/m²/day	@50°C 100% RH

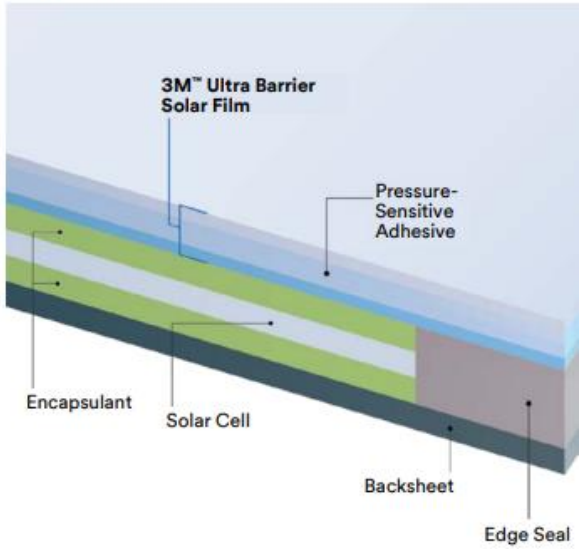
Features

- Good optical transmission from 400 – 1400 nm
- Very low moisture vapor transmission rate
- Excellent UV stability
- Flexible

Key Highlights

- UL Certified Component (E316895)
- WVTR: < 6×10^{-5} g/m²/day @ 50°C, 100% RH
- Transmission > 90% (Avg 400 nm – 1400 nm)
- Low Shrinkage: 0.15%
- Partial Discharge 1,000V
- Low CTE

Typical Flexible PV Module Construction



3M™ Charge-Collection Solar Tape 3011

Applications

3M Charge-Collection Solar Tape 3011 and 3011B are designed for use as a charge collector or bus within a thin-film solar module. 3M Charge-Collection Tape 3011B is designed for applications that require the bus on the front side of the module. The adhesive was formulated to undergo the vacuum lamination process typically used in the manufacture of solar modules.

3M™ Adhesive Transfer Tape 966

The 3M™ Adhesive Transfer Tapes with 3M™ High Temperature Acrylic Adhesive 100 are designed for temperature exposure to 450°F (232°C) for short periods of time and/or solvent resistance. They have exceptional shear values even at elevated temperatures. They also offer low “outgassing” properties, which is an important consideration for the aerospace, automotive and electronic industries.

Cover Films for Satellite Solar Cell Arrays

Advantages:

- Easy to use and scale via R2R processing
- Domestic supply
- Additional functionality can be incorporated
  - Moisture barrier
  - High angle of incidence light-capture
  - Adhesives

Performance Requirements:

- Low earth orbit durable
  - AM0
  - AO
  - e-/p+ radiation
- High visible transparency
- Stable -100C to +120C
- Low outgassing

Cover films: Proton and Gamma Radiation

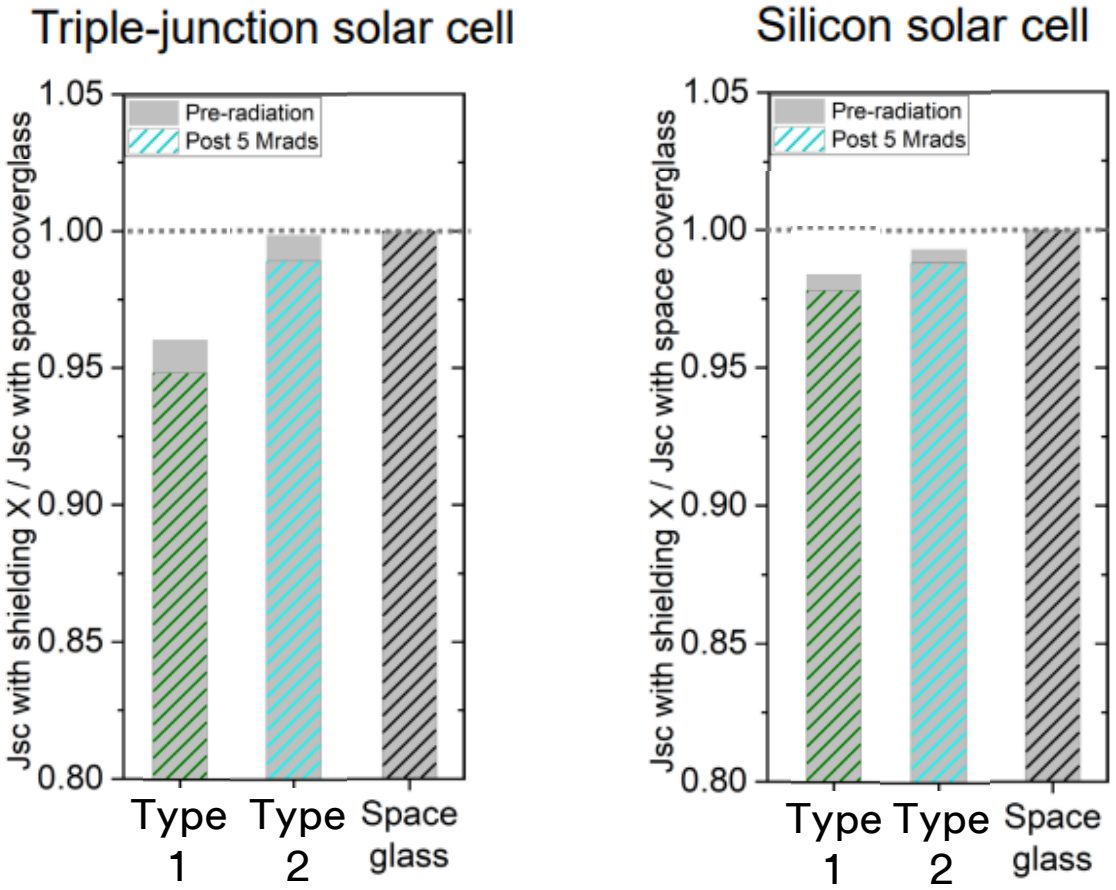
Courtesy of Aerospace Corporation / Pilar Espinet Gonzalez

Proton radiation exposure

Type 1:

99.1% retention of BOL silicon solar cell Jsc after 5 years ISS equivalent proton radiation exposure

Gamma radiation exposure



Calculated Jsc from transmission spectra of film/glass, AM0 spectrum, and EQE of solar cells

Cover Film: Atomic Oxygen Durability

	1E21 atoms/cm2 exposure		
Material	**Mass retention (%)**	**Mass loss per atom (mg/atom)**	**Erosion yield (cm3/atom)**
3M Solar cell film	99.94%	1.9E-23	1.5E-26
Kapton for reference			2.8E-24
FEP for reference			2.0E-25

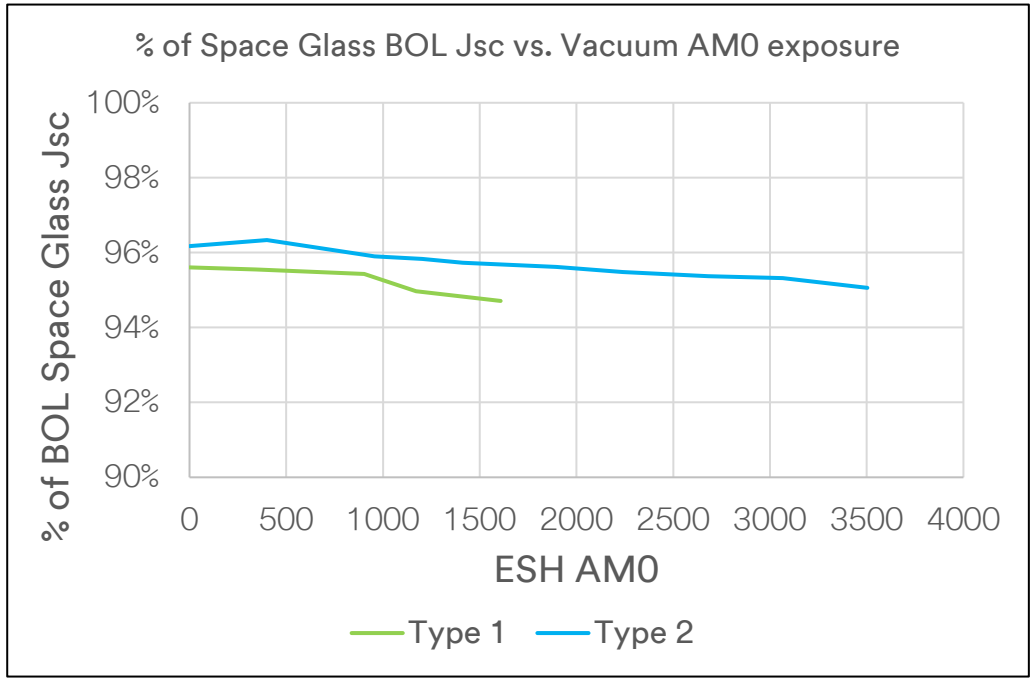
<0.1% mass loss after 1E21 atoms/cm^2 atomic oxygen exposure

Data from Type 2 film, but representative of Type 1 performance

Cover Films: Vacuum AM0 Durability

3M Vacuum AM0 Exposure (no VUV component)

	% of BOL 1J Jsc		**% of BOL Space Glass 1J Jsc**		
Sample type	*After actual exposure*	*Projected to 22000 ESH Vac AM0*	**BOL**	**After actual exposure**	**Projected to 22000 ESH Vac AM0**
Type 1 (1600 ESH AM0)	*99.1%*	*86.9%*	**95.6%**	**94.7%**	**83.1%**
Type 2 (2200 ESH AM0)	*99.3%*	*92.4%*	**96.2%**	**95.5%**	**88.9%**



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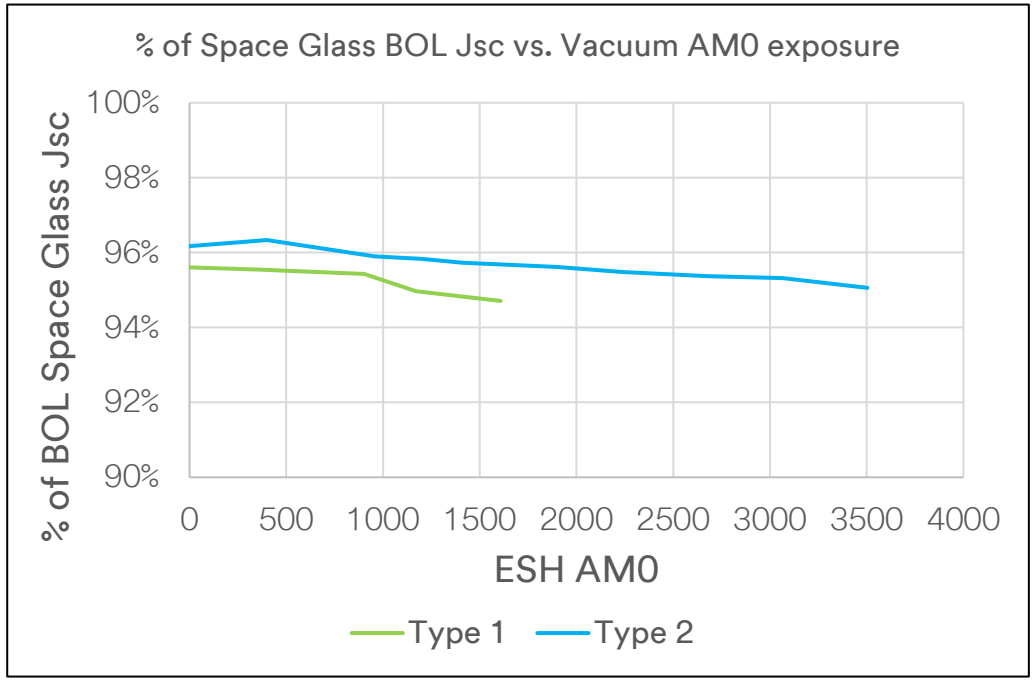

Aerospace Corp Vacuum AM0 Exposure (2000 ESH exposure)

	% of BOL 1J Jsc		% of BOL Space Glass 1J Jsc		
Sample Type	*2000 ESH Vac AM0*	*Projected to 22000 ESH Vac AM0*	**BOL**	**2000 ESH Vac AM0**	**Projected to 22000 ESH Vac AM0**
Type 1	*98.9%*	*87.6%*	**97.9%**	**96.7%**	**85.7%**
Type 2	*98.4%*	*82.9%*	**96.5%**	**95.0%**	**80.1%**

Cover Films: Vacuum AM0 Durability

3M Vacuum AM0 Exposure (no VUV component)

	% of BOL 1J Jsc		% of BOL Space Glass 1J Jsc		
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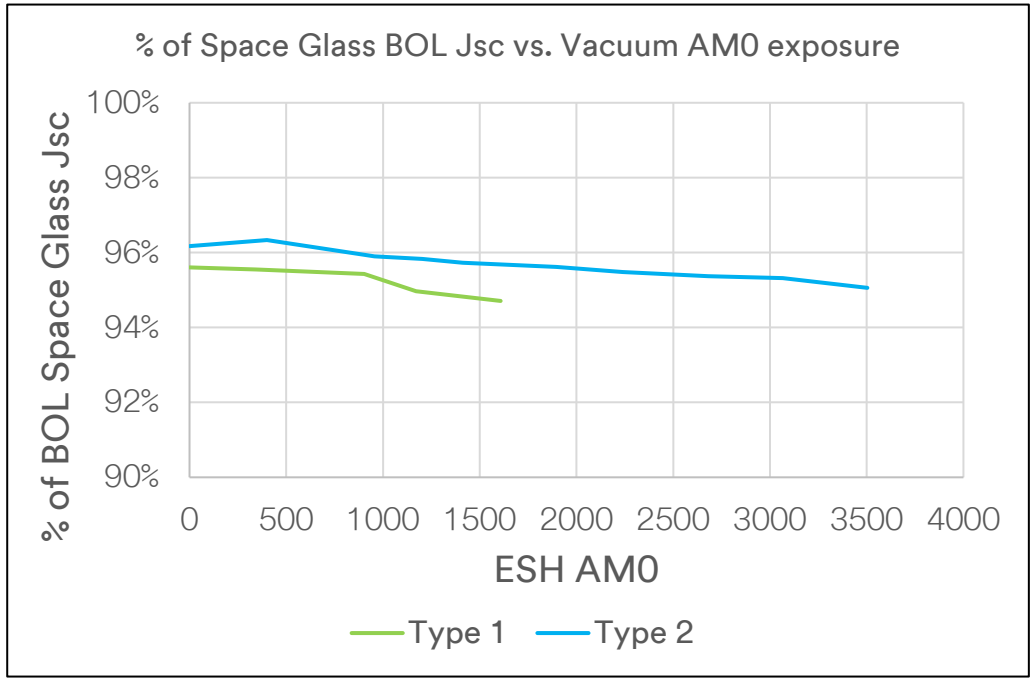


Type 1 projected at EOL (22,000 ESH):

- 87-88% Jsc retention
- 83-86% Jsc retention normalized to BOL Space Glass

Type 2 projected at EOL (22,000 ESH):

- 83-92% Jsc retention
- 80-89% Jsc retention normalized to BOL Space Glass

Longer exposures needed for more accurate EOL predictions

Cover Films: Outgassing Performance

Courtesy of Aerospace Corporation / Abraham N. Buditama & Pilar Espinet Gonzalez

Polymer Substrate Type	Total mass loss (%) (Target <1%)	Collected volatile condensable materials (%) (Target <0.1%)
Type 1	0.275 +/- 0.004%	0.002 +/- 0.007%
Type 2	0.998 +/- 0.284%	0.035 +/- 0.013%

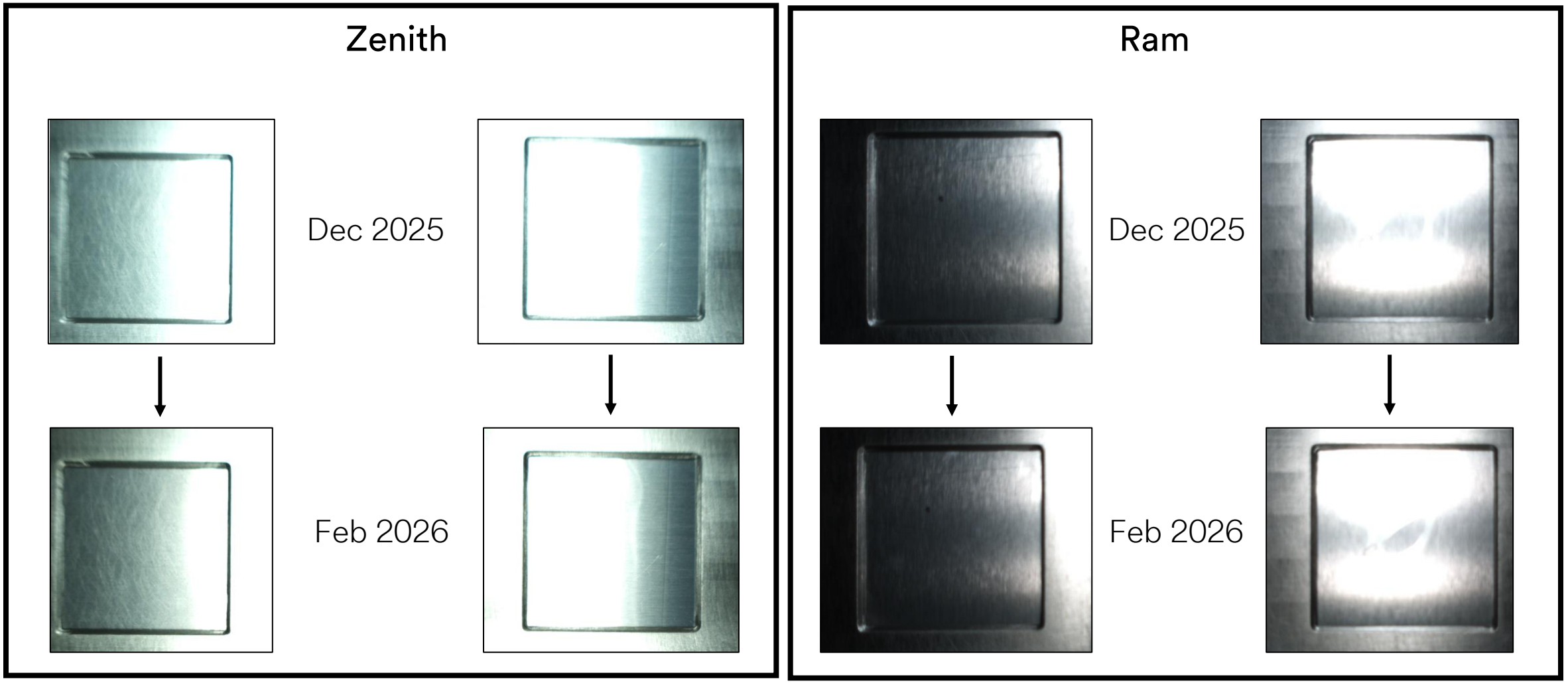
Type 1:

- Passes TML
- Passes CVCM

Type 2:

- On the edge of passing TML
- Passes CVCM

Cover Films: MISSE-21 Images



No obvious degradation (yellowing or hazing) after 2 months ISS exposure

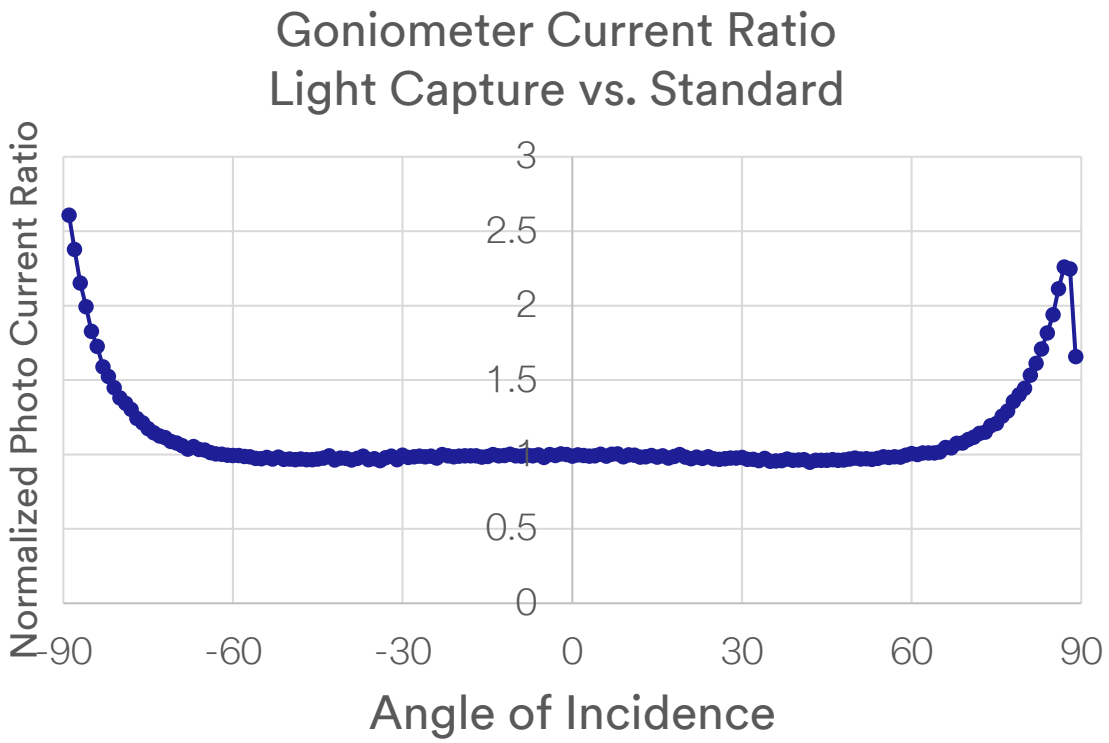
Cover Films: Additional Functionalities

Moisture Barrier

Typical Properties

Properties	Test Method	Typical Values*	Comment
Water Vapor Transmission Rate	Mocon, Aquatran	< 6×10^{-5} g/m²/day	@50°C 100% RH

Increased Light Capture at High Angles of Incidence



Solar cell film can be combined with adhesives (PSA, hot melt, etc.)

Cover Films: Summary

3M cover films provide durable, scalable performance for LEO solar cells

- LEO-durable:
  - Vacuum AM0
  - AO
  - e-/p+
- Low-outgassing
- Retains ~90% Jsc after 22,000 ESH Vac AM0 (projected)
- Films can incorporate additional functionalities:
  - Moisture barrier
  - High angle of incidence light-capture
  - Integration with PSAs or encapsulants