

Advanced Technology Laboratories

Semiconductor Overview

John Monk

June 5, 2023

Our Business

Northrop Grumman's business sectors offer an extraordinary portfolio of capabilities, technologies, and workforce talent that combine to help our customers around the world meet their most complex challenges across the air, cyber, land, sea and space domains.

Aeronautics Systems



Aeronautics Systems is a premier provider of military aircraft, autonomous systems, aerospace structures and next-generation surveillance, strike and commercial solutions.

Headquarters: Palmdale, Calif.
(Los Angeles area)

Defense Systems



Defense Systems delivers full-spectrum defense capabilities that provide mission-ready, all-domain decisions and effects to a wide variety of national security, military and civil customers.

Headquarters: McLean, Va.
(Washington, D.C. area)

Mission Systems



Mission Systems is a technology leader in open, cyber-secure, software-defined systems for defense and intelligence applications across multiple domains.

Headquarters: Linthicum, Md.
(Baltimore area)

Space Systems



Space Systems is an industry leading provider of end-to-end space and launch systems and capabilities serving national security, civil and commercial customers.

Headquarters: Dulles, Va.
(Washington, D.C. area)

Northrop Grumman Advanced Technology Laboratories (ATL)

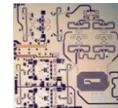
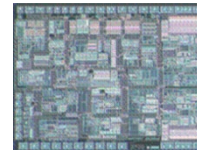
DoD Trusted Foundry for Wafer Fabrication, Assembly, and Test

Over 58,000 square feet of wafer fabrication cleanroom supporting discriminating technologies for USG / DoD Systems

- Silicon, GaAs, SiC, GaN
- Mixed signal ASICs, MMICs, Power Transistors, Rad-hard ASICs
- Superconducting Electronics
- Advanced Testing of Commercial, deep node, Semiconductor Chips

More than 850,000 devices delivered in 2022 to over 38 programs of record and an additional >1,000,000 to developmental programs

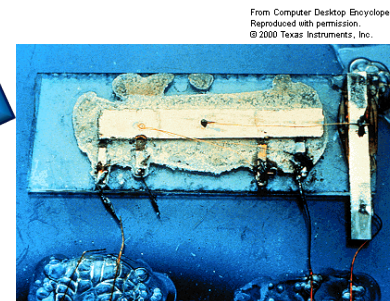
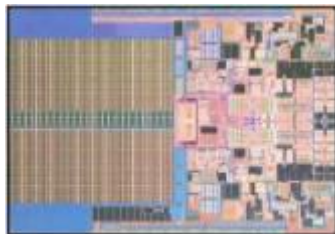
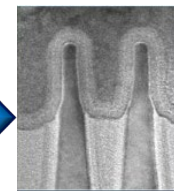
>800 Experienced technical staff, over 75 subject matter experts



High Mix, DoD Volume Production and R&D Facility

What are We Talking About?

- **Semiconductors** are materials that can be either an insulator or a conductor
 - Silicon, Germanium, Gallium Arsenide, Gallium Nitride, Silicon Carbide are the main materials used
- The first transistor was invented in 1947
 - It fit in the palm of your hand
 - Today we are at the 7nm node for production
- The first integrated circuit (Chip) was invented in 1958
 - It consisted of two transistors
 - Today there can be >50 billion on a 2cm by 2cm chip



From Computer Desktop Encyclopedia
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ATL Technologies Support Defense Needs For High-Mix / DoD-Volume Microelectronics

Over 30 Production Processes, more in development

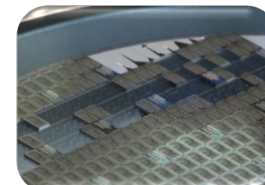
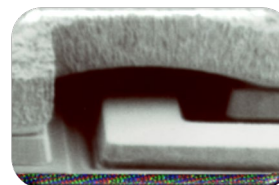
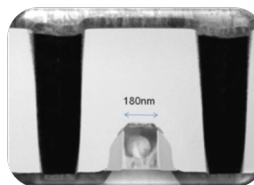
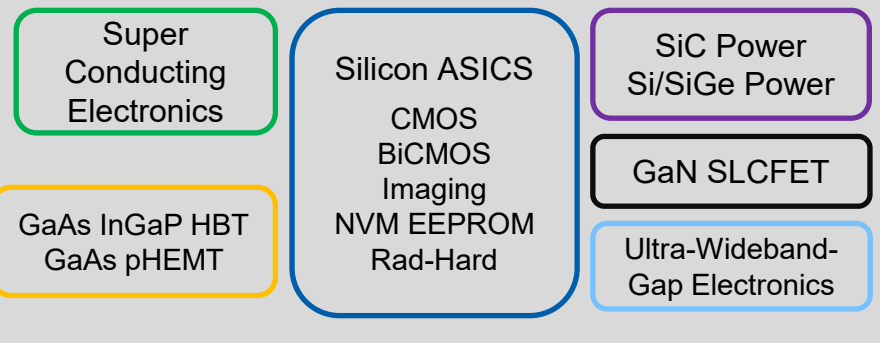
Production

- CMOS – 0.5um, 0.8um, 1.2um
- BiCMOS – 15v, 40v, 60v, 100v
- SiGe Bipolar Power
- SiC – Schottky SIT Power
- Imaging – ITO CCD
- GaAs - InGaP HBT, pHEMT
- GaN SLCFET Switch & Filters

Development

- GaN SLCFET Amplifiers and Diodes
- RQL – Reciprocal Quantum Logic
- Ultra-Wideband Gap Electronics

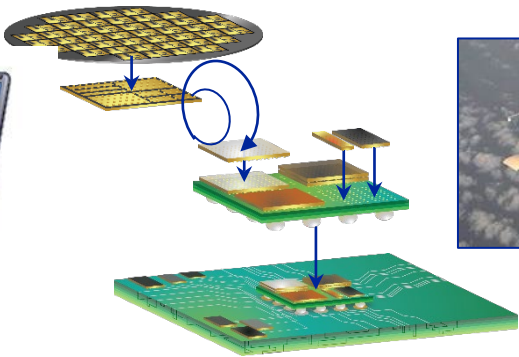
Supporting a Strong Mix of Technologies



ATL is Unique

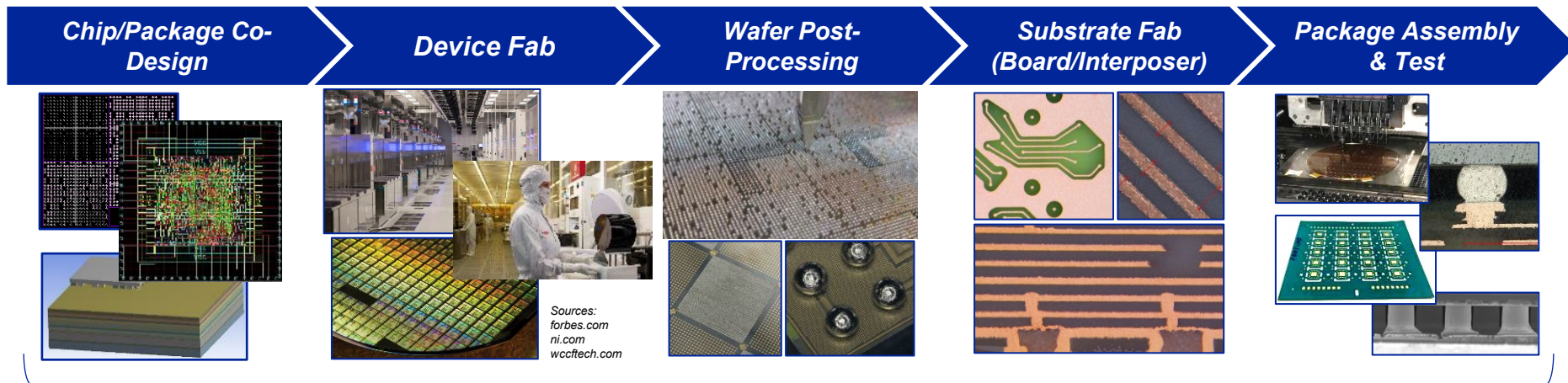
NO OTHER Facility in the US Has This Variety of Semiconductor Technologies Under One Roof!

Everything Depends on Microelectronics

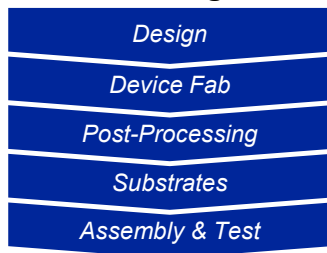


Creating Microelectronics

Design, Manufacturing, and Test Are Interconnected

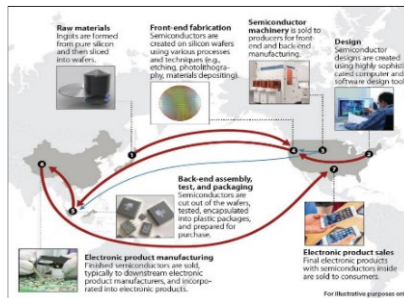


Vertical Integration



VS.

"FedEx® Flow"



USA		Asia
85%	Semiconductor Design	5%
12%	Fab / Manufacturing	75%
3%	Packaging	97%

Congressional Research Service (2020): <https://crsreports.congress.gov/product/pdf/R/R46581>
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IPC Advanced Packaging Ecosystem Report (2021)
& U.S. Department of Defense

Semiconductor Industry Evolution



Moore's Law:
Minimum feature size (node) will be reduced by half every two years

Rock's Law:
Fab costs will double for every node

New state of the art
fabs cost \$10B - \$20B

* Moore's law states that the number of transistors in an integrated circuit chips doubles every 2 years
Data referenced from Intel and WikiChip

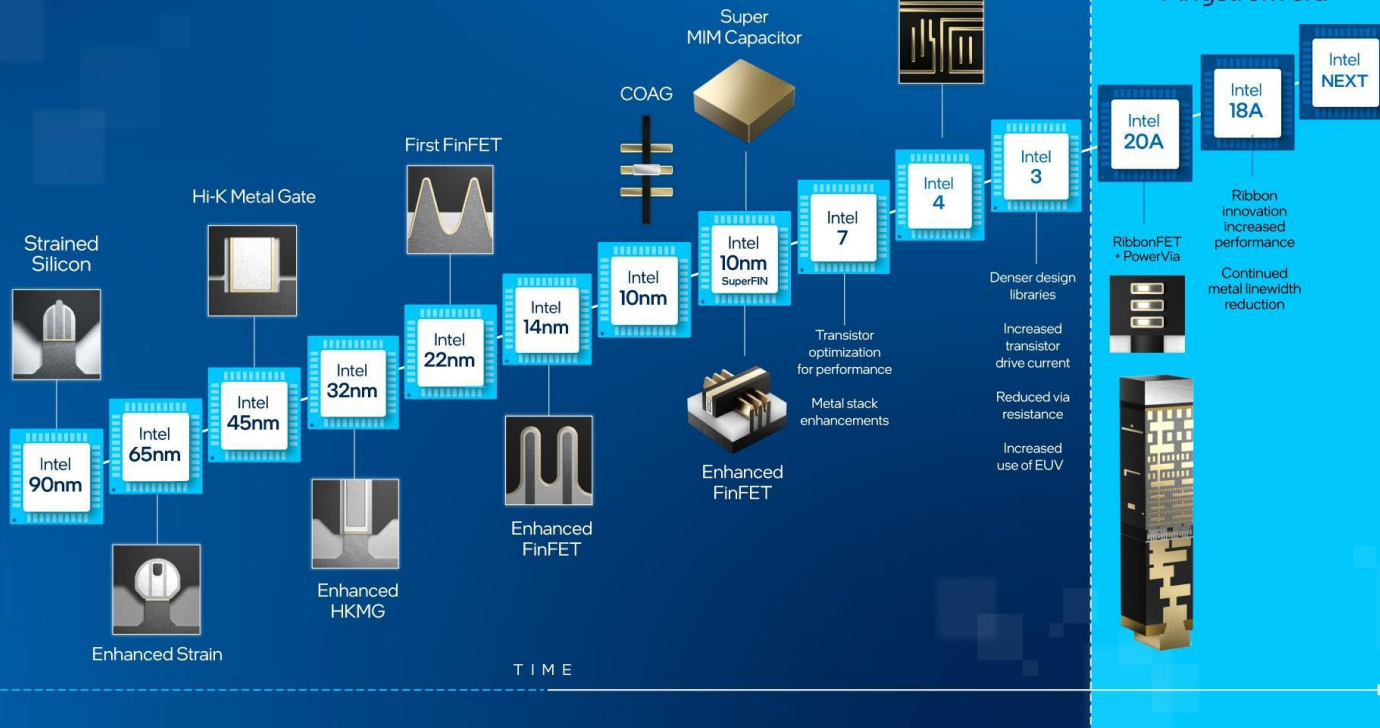
Data referenced from Intel and WikiChip
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Microelectronics Scaling

intel.

PERFORMANCE PER WATT

TIME



Pin Head
2 mm



Human Hair
>90,000 nm

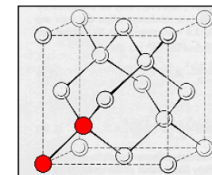


Wavelength of
Visible Light
500 nm



The average diameter of coronaviruses
is about 120 nanometers

Silicon



Source: Princeton

Nearest neighbor: 0.235 nm
Lattice parameter: 0.543 nm

The CHIPS Act

What is it?



NORTHROP
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Agency/Program	Five-Year Authorization	Portion	RFP (FOFO)	Notes / Known Limitations
Department of Commerce (Commerce) <ul style="list-style-type: none"> Incentives program to bolster domestic manufacturing capacity including funds for: <ul style="list-style-type: none"> Legacy chip production Industry loans and loan guarantees Creation of National Semiconductor Technology Center, National Advanced Packaging Manufacturing Program, and associated research and workforce development programs 	\$50 billion total including: "9902" \$2 billion \$6 billion \$11 billion "9906"	SoTA "Leading-Edge Facilities" Constructing, Expanding or Modernizing Fab Construction (<13nm)	Started May 2023	<ul style="list-style-type: none"> Restriction on semiconductor manufacturing capacity expansion in foreign countries of concern Expecting cost-share and commitments from state/local. Grants expected to be 5% to 15% of total capital costs, not exceeding 35%
Department of State – Establishing a new program to coordinate the development of secure and trusted emerging technologies with foreign governments	\$500 million	"Current-Generation Facilities" (<28nm)	"Fall" 2023 (Rolling)	Assumed similar to above
		SoTP "Mature Node Facilities"	Later then Fall 2023 (Rolling)	"At Least" \$2B Assumed similar to above
		NSTC – National Semiconductor Technology Center	"Fall" 2023	<ul style="list-style-type: none"> Department of Commerce has sent out white paper with high level expectations and has asked for feedback Workforce development is key part of this
National Science Foundation (NSF) – Funding to promote growth of the domestic semiconductor workforce	\$200 million	NAPMP – National Advanced Packaging Manufacturing Program	Likely 2024	Not much known / released about this program.
Other Programs <ul style="list-style-type: none"> CHIPS for America Defense Fund (sponsoring university-based prototyping of semiconductor technologies, including for defense applications) Wireless Supply Chain Innovation (sponsoring leap-ahead technologies that spur movement towards open-architecture and software-based wireless technologies) Advanced tax credit for companies investing in semiconductor manufacturing 	\$2 billion \$1.5 billion ~ \$24 billion*	Portion	RPQ (FOFO)	Notes / Known Limitations
		"ME Commons"	February 2023 (Closed Now)	<ul style="list-style-type: none"> FRP closed to form the regional Hubs. Expect a yearly call for project proposals which we can shape Concern about "peanut butter" spreading of the funding resulting in minimal actual work
		Portion	RPQ (FOFO)	Notes / Known Limitations
		Tax Credit	CY23 – CY26	Any investments into Microelectronics equipment in 2023 – 2026 are subject to a 25% tax credit.

Chips were invented in America

But most chips are made outside of the U.S.



Logic chip production by country, 2021



Memory chip production by country, 2021



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CHIPS for America Vision



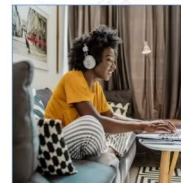
Economic Security

This act enables us to build more resilient supply chains for important components.



National Security

This act enables us to bring the most sophisticated technologies back to the U.S.



Future Innovation

Chips are key to the technologies and industries of the future, so we need to be at the forefront. This act will ensure long-term U.S. leadership in the sector.

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CHIPS for America will:



Return leading-edge chip manufacturing to U.S.



Expand capacity to make current/mature chips and critical supplies



Reinforce U.S. strengths in chip design and equipment



Grow a U.S. workforce and strengthen communities

Create a domestic semiconductor ecosystem for national and economic security

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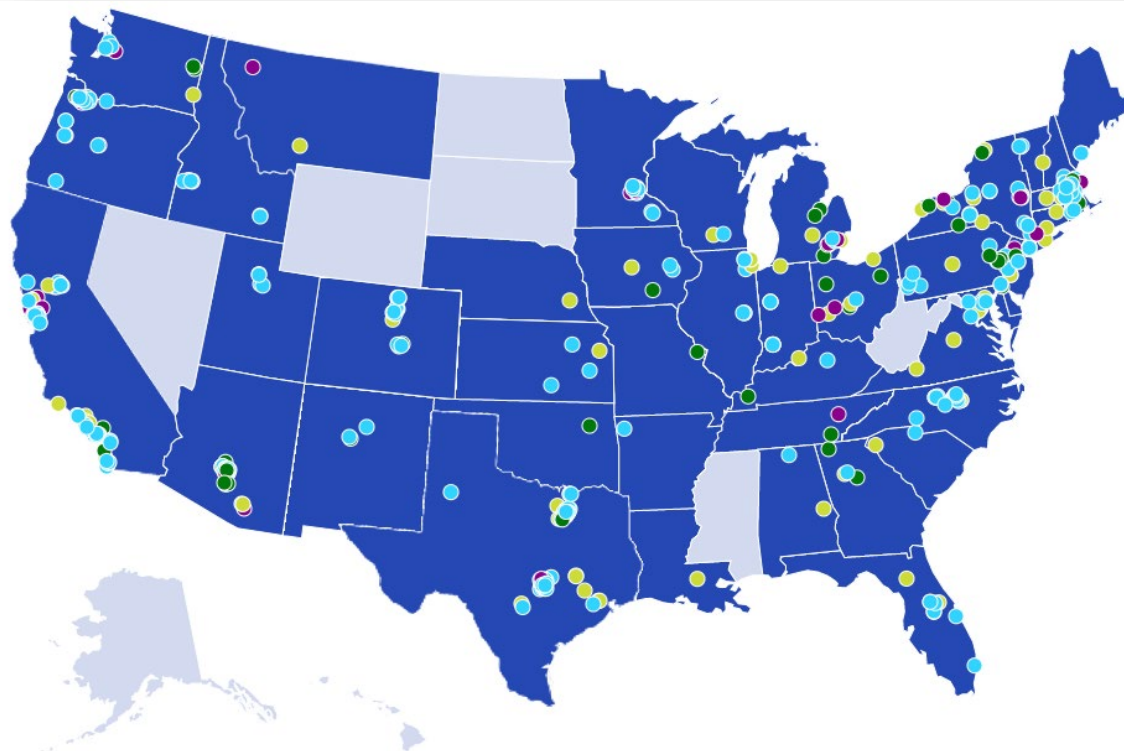
Guiding Principles



- 1 Meet economic and national security needs
- 2 Ensure long-term leadership in the sector
- 3 Strengthen and expand regional clusters
- 4 Catalyze private sector investment
- 5 Generate benefits for a range of stakeholders and communities
- 6 Protect taxpayer dollars

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New / Expanding Semiconductors Facilities Watch List



● Semiconductors ● Equipment ● Materials ● University R&D Partner

Fab, IDM or OSAT	State	Fab, IDM or OSAT	State	Fab, IDM or OSAT	State
Wolfspeed	AR	Trusted Semiconductor Solutions	IN	Intel	OH
Compound Photonics	AZ	Everspin Technologies	IN	Rogue Valley Microdevices	OR
Lansdale	AZ	NHanced Semiconductors	IN	Alpha & Omega Semiconductor	OR
TSMC	AZ	SkyWater Technology	IN	onsemi	OR
Amkor	AZ	EMP Shield	KS	Microchip Technology	OR
Microchip Technology	AZ	Radiation Detection Technologies	KS	Intel	OR
Intel	AZ	Integra Technologies	KS	Analog Devices	OR
Infineon Technologies	AZ	Infineon Technologies	KY	Infineon Technologies	OR
NXP	AZ	TSMC	WA	Qorvo	OR
Vishay Intertechnology	CA	Analog Devices	WA	Mitsubishi Semiconductor	PA
Keysight Technologies	CA	Infineon Technologies	WA	Infinaera	PA
Samsung	CA	Littelfuse	WI	Coherent	PA
SK hynix	CA	Rochester Electronics	MA	onsemi	PA
Infinaera	CA	Massachusetts Bay Technologies	MA	Infineon Technologies	RI
Northrup Grumman	CA	MACOM Technology Solutions	MA	Pallidus	SC
TSI Semiconductors	CA	Luminar	MA	X-FAB	TX
pSemi	CA	Littelfuse	MA	Intel/Tower	TX
Akoustis	CA	Skyworks	MA	NI	TX
Tower Semiconductor	CA	Analog Devices	MA	Samsung	TX
Luminar	CA	Infineon Technologies	MA	Infinaera	TX
Solidigm	CA	Infinaera	MD	Tower Semiconductor	TX
Littelfuse	CA	Northrup Grumman	MD	Littelfuse	TX
Western Digital	CA	Skyworks	MD	Texas Instruments	TX
Skyworks	CA	Diodes Incorporated	ME	Coherent	TX
Skyworks	CA	Texas Instruments	ME	Infineon Technologies	TX
Kioxia	CA	Honeywell Aerospace	MN	NXP	TX
Kioxia	CA	Polar Semiconductor	MN	Qorvo	TX
Coherent	CA	SkyWater Technology	MN	Texas Instruments	UT
Intel	CA	Infineon Technologies	NC	Micron	VA
Infineon Technologies	CA	Qorvo	NC	GlobalFoundries	VT
Wolfspeed	CA	Wolfspeed	NC	Honeywell Aerospace	WA
Solidigm	CO	onsemi	NH		
Microchip Technology	CO	Intel	NM		
Infineon Technologies	CO	Odyssey Semiconductor	NY		
Coherent	DE	MACOM Technology Solutions	NY		
SkyWater Technology	FL	GlobalFoundries	NY		
Renesas Electronics	FL	Akoustis	NY		
Northrup Grumman	FL	Micron	NY		
Luminar	FL	onsemi	NY		
LA Semiconductor	ID	Wolfspeed	NY		
Micron	ID				
onsemi	ID				
Littelfuse	IL				

Trusted Microelectronics at Northrop Grumman ATL

Advanced Technology Labs (ATL) Delivers Products & Expertise

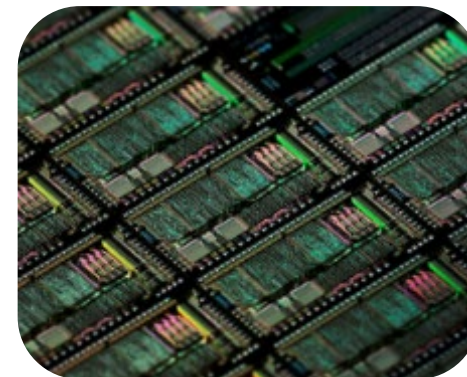
In-house design, production, assembly & test to support a range of microelectronic technologies

Delivering products to NGMS programs daily

Internal products have features not found in COTS' that leverage new business

Active R&D group creating discriminators

Over 50-year legacy with AS9100 and Trusted Status



Delivering Assured Production and Discriminating R&D

NORTHROP
GRUMMAN

The logo graphic consists of a thick horizontal line extending from the end of the word "NORTHROP", which then turns 90 degrees downward to form a vertical line of the same thickness, ending at the level of the word "GRUMMAN".