Artificial Intelligence Applied to Failure Detection in Space

AI for Industry International Congress, 28-29.04.2021 secpho

ALTER
TECHNOLOGY

"THE TÜV NORD GROUP IS A GLOBAL LEADER IN TECHNOLOGY SERVICES WITH THE CLEAR AIM OF ACCOMPANYING ITS CLIENTS WITH PRUDENCE AND FORESIGHT INTO THE FUTURE."

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TüV NORD Group at a Glance

ALTER TECHNOLOGY

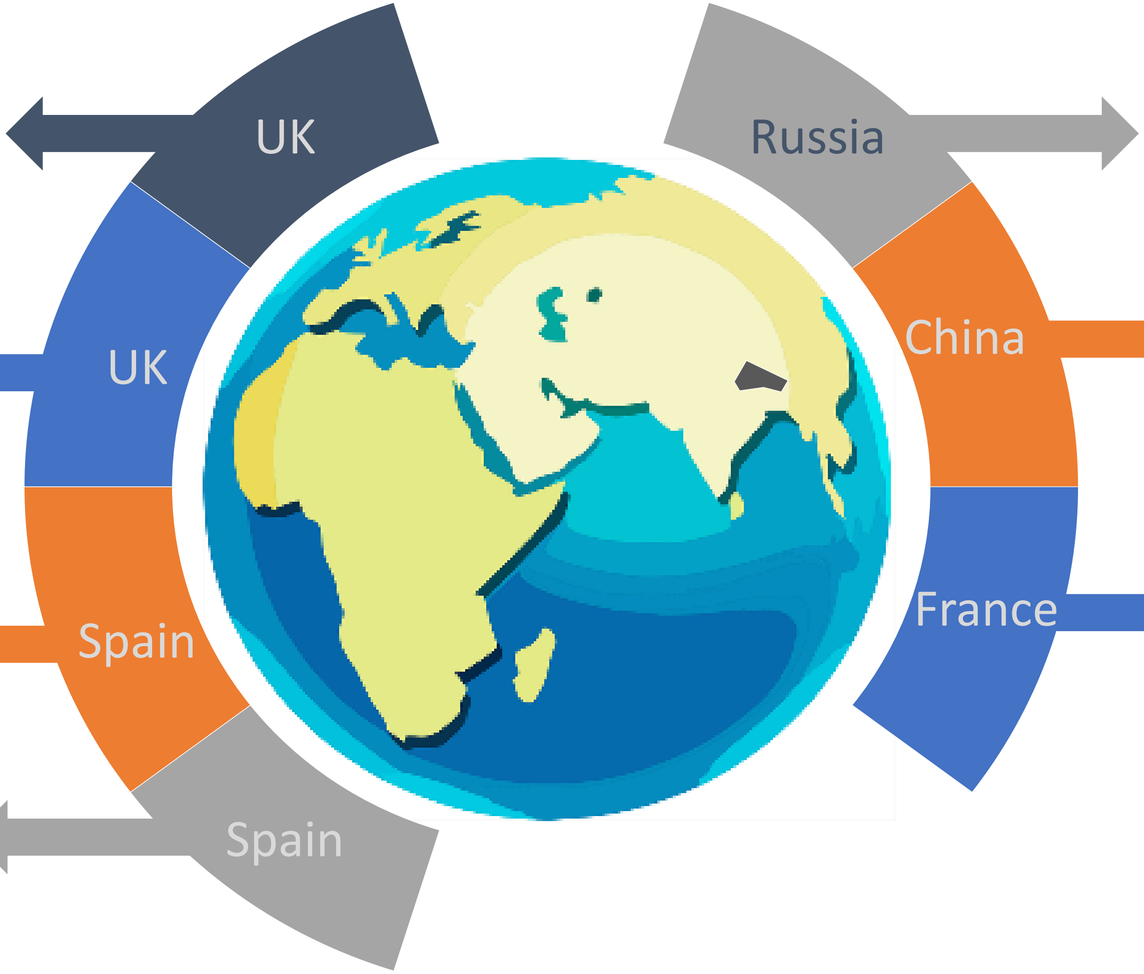
50
companies

100
countries services are carried out

10,780
employees

1,229
M€ revenues

ALTER Technology in the world



Edinburgh
Optoelectronics, microelectronics and MEMS, packaging design & assembly services

Portsmouth
Sales and business development site

Madrid
Certification, equipment and optoelectronics laboratories, innovation, commercial teams

Seville
EEE laboratory, engineering, radiation facilities, innovation, procurement and space projects management

S.Petersburg
Sales and business development

Shanghai
Sales and business development

Toulouse
EEE laboratory, radiation. Space, aeronautical and automotive focus

Business areas

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Hi-Rel components

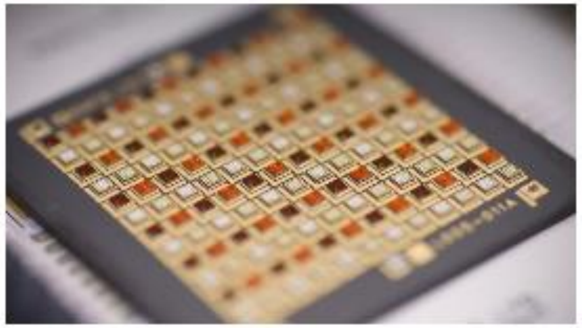
Engineering, Testing and Procurement

Electronic Systems

Testing and CE Marking

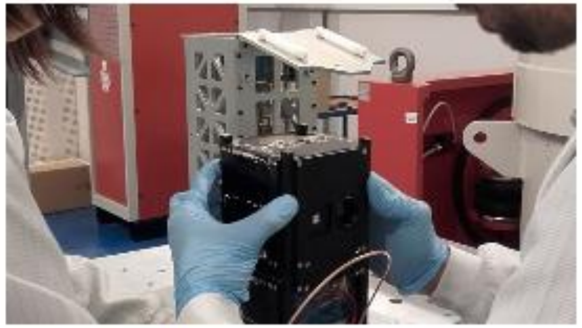
Alarm Systems

Conformity of security systems



Packaging and Assembly

For opto and microelectronic devices



Small Satellites

Quality assurance and test to small satellites

Drones

Compliance and assurance of safety standards

Automotive

Engineering, testing and certification services.

Other services

Certification, CE Marking, Alarm Systems

Number of active satellites from 1957 to 2020

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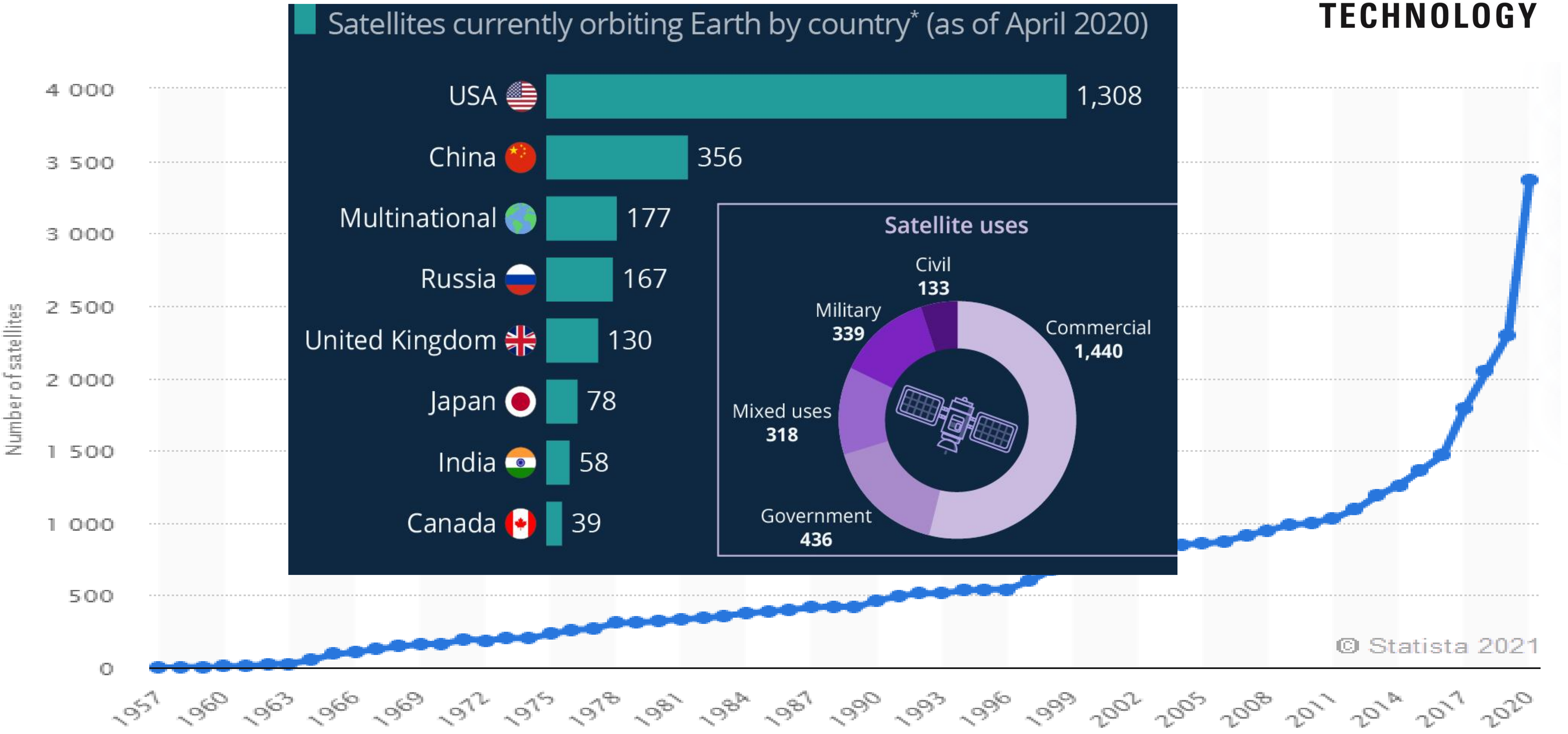

Where Data Science were applied in 2017-18

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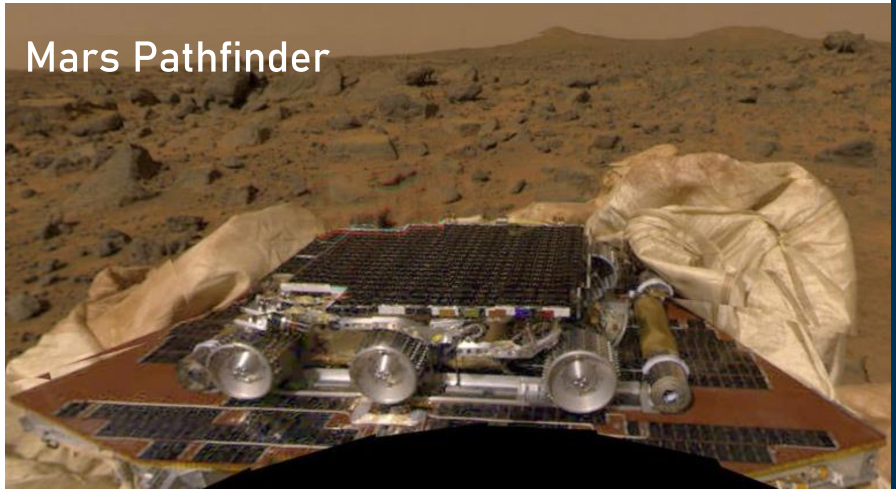
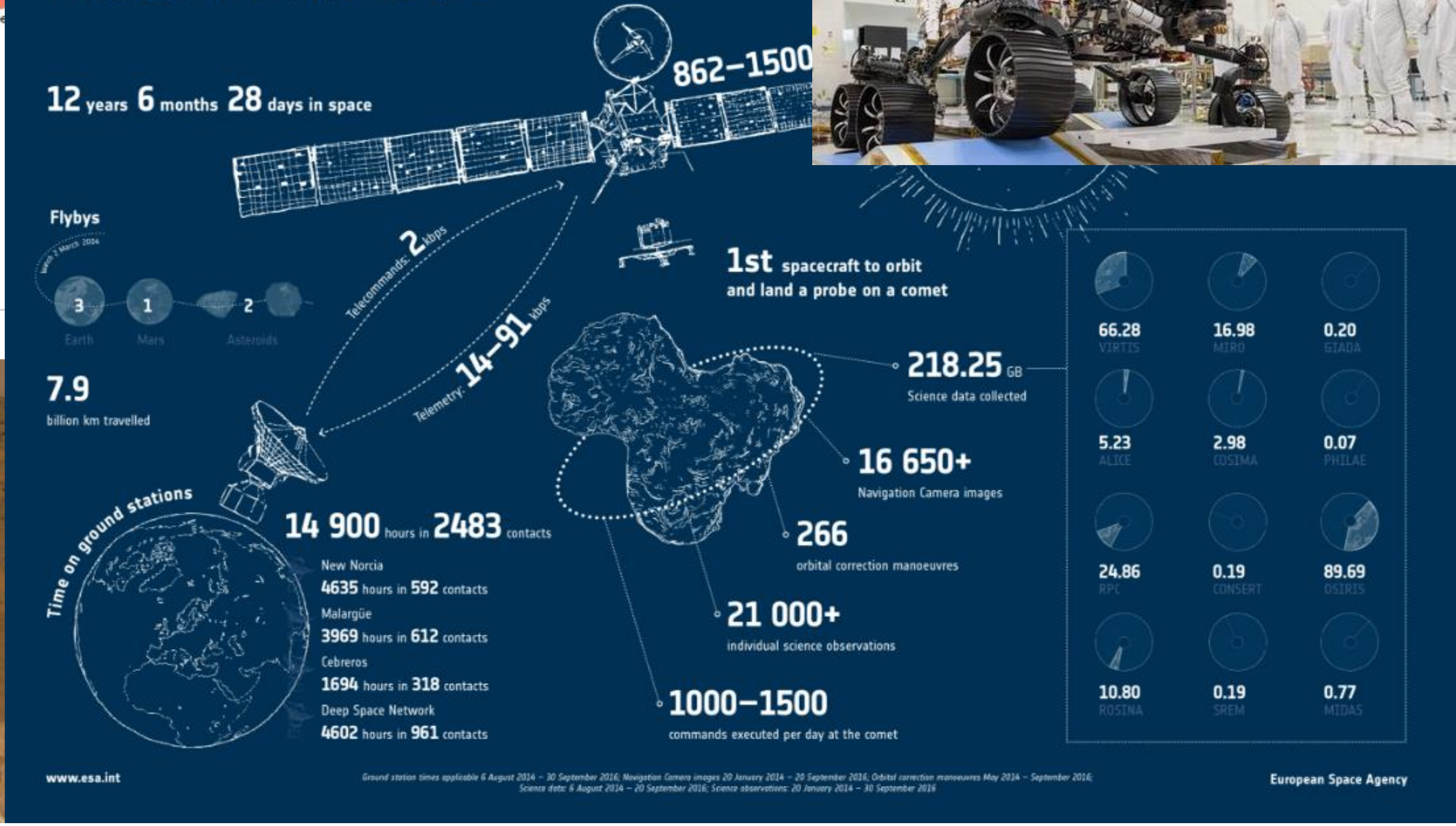
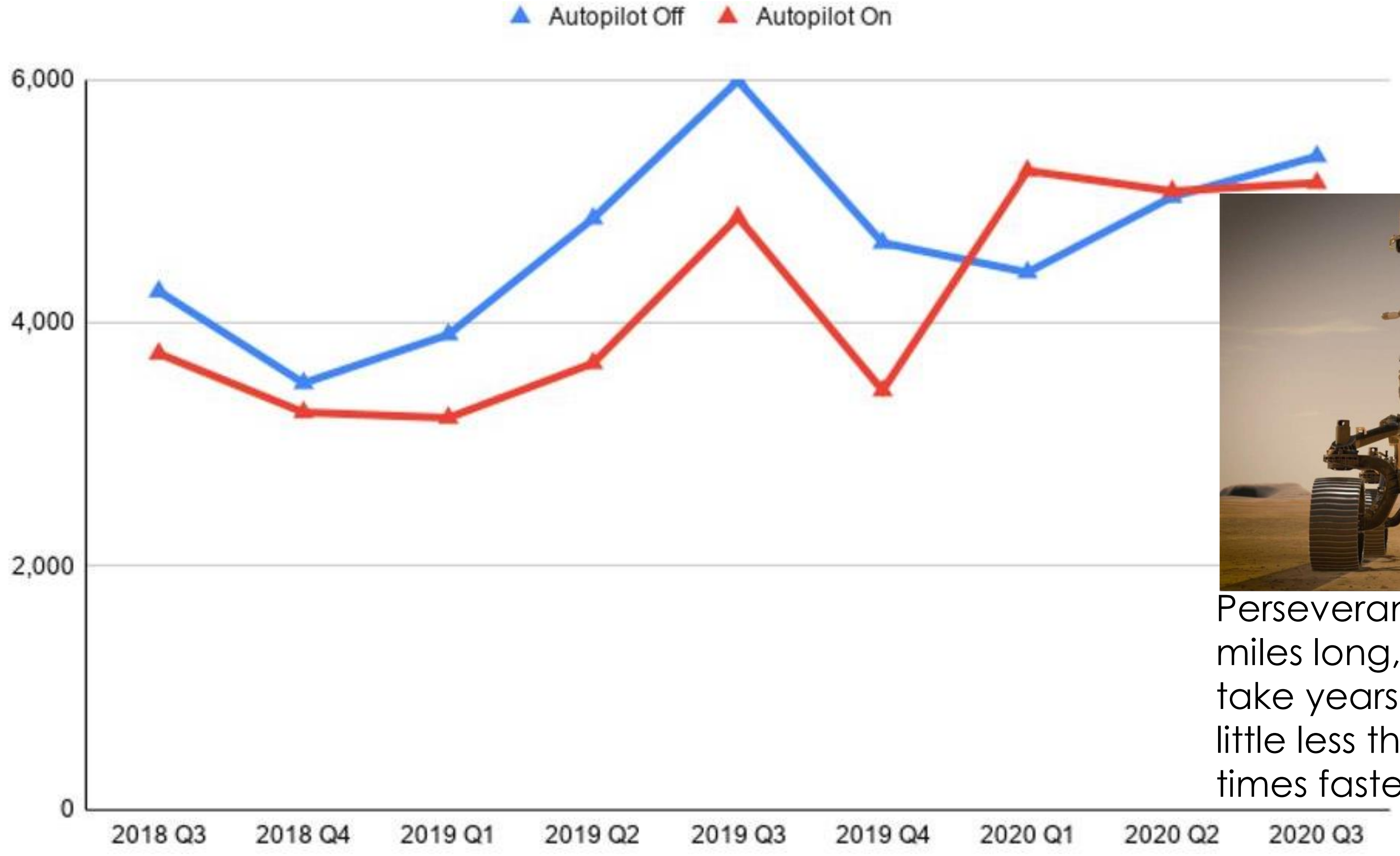
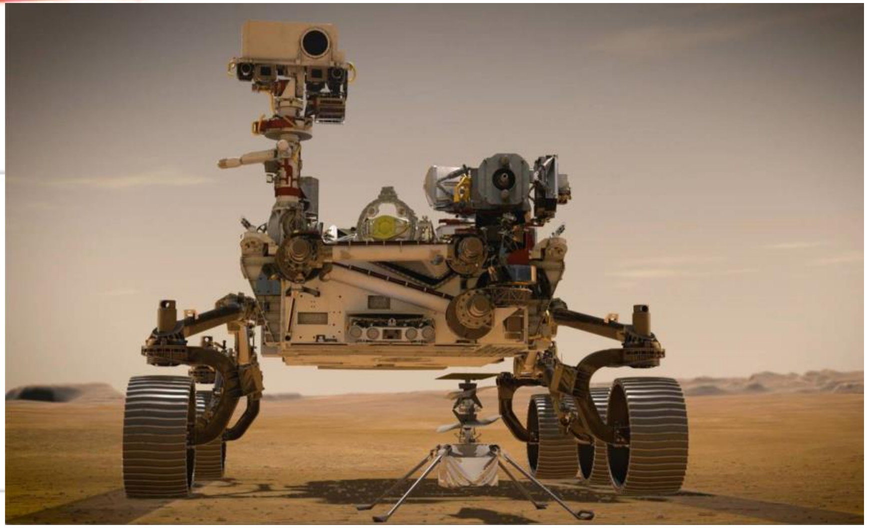




Thousand Miles per Accident with Tesla





Perseverance will traverse is about 15 miles long, an "epic journey" that will take years. Perseverance will drive a little less than **0.1 mile per hour**, three times faster than previous rovers.

© Brad Templeton, Forbes.

Relative Explainability Learning Algorithms

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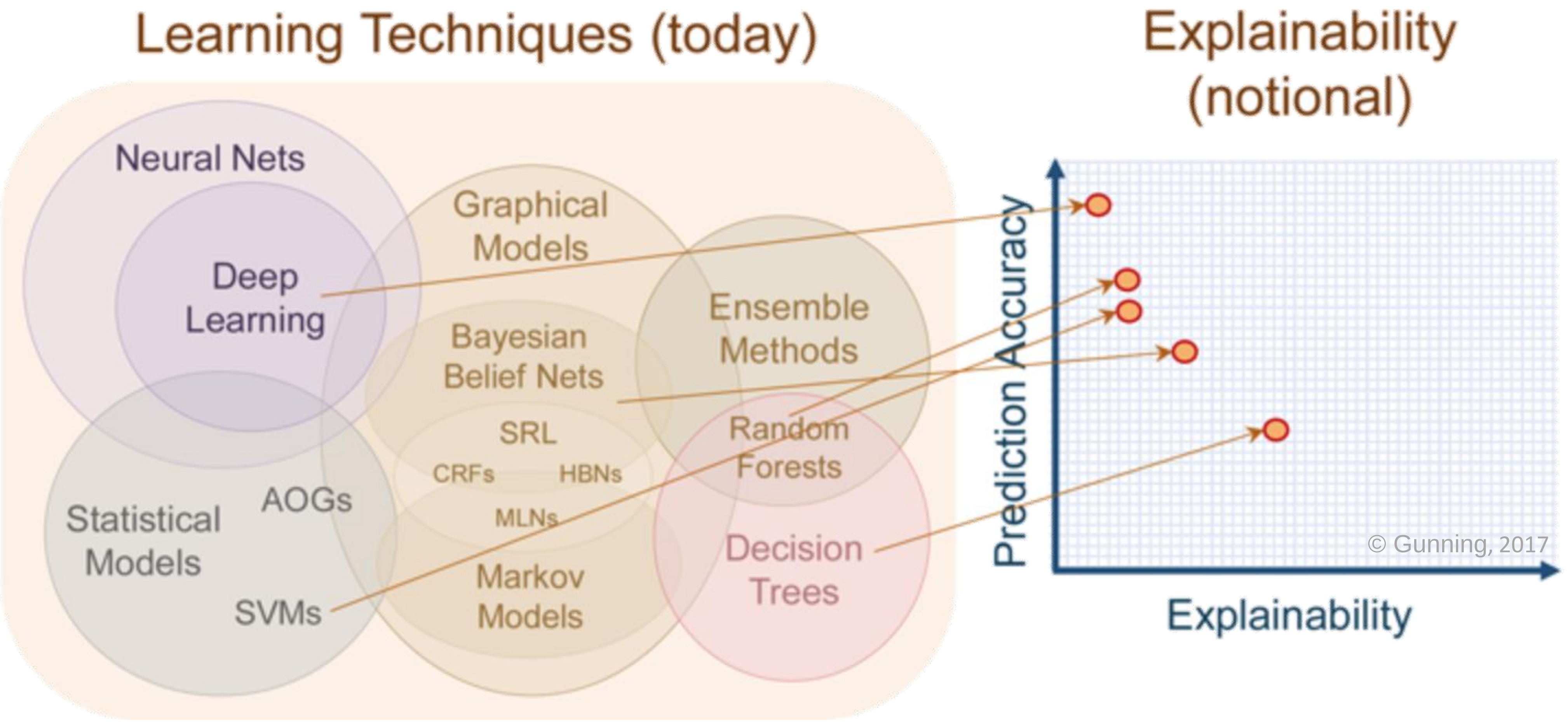

Large integration

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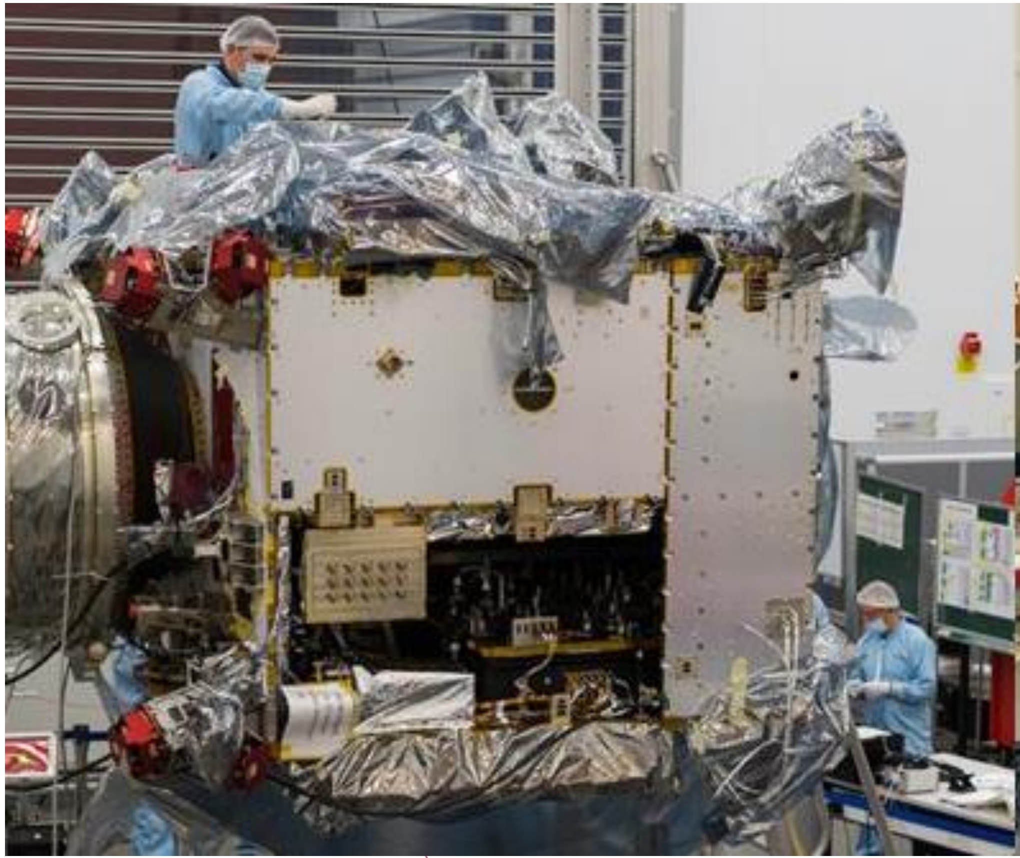

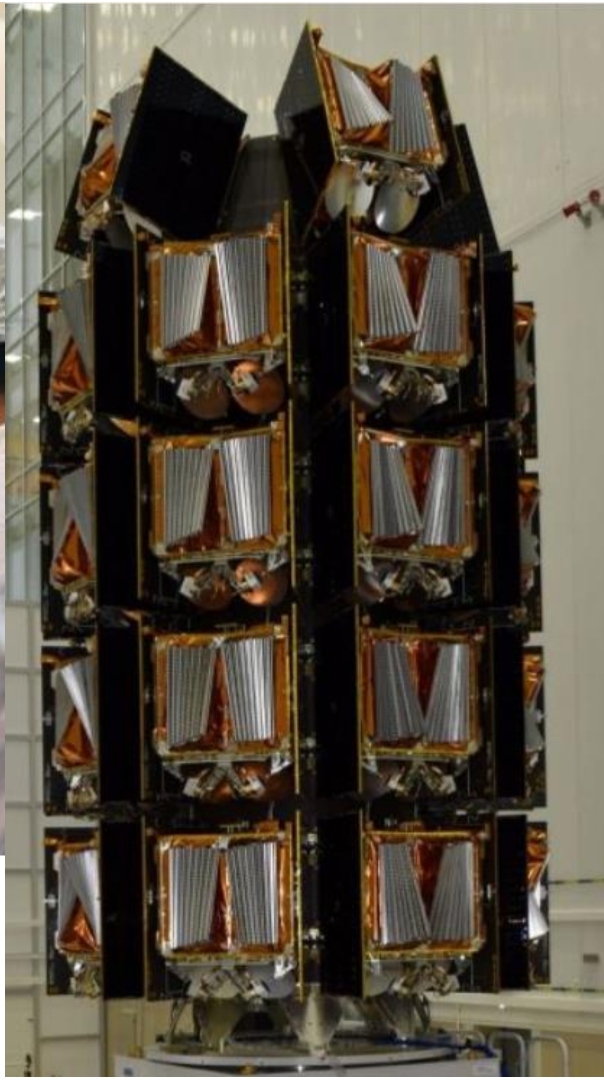

solar orbiter

OneWeb

Number of active satellites from 2016 to ....

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Company	No. Sats	Sats Size	Orbit	Year (Operative)	Reference
Globalstar Inc.	48	Medium	LEO	?	[49]
Iridium Inc. - Aieron	75	Medium	LEO	2019	[50]
OneWeb	648	Mini	LEO	?	[51]
O3b (SES mPower)	27	Medium	MEO	2021	[52]
Orbcomm	11	Mini	LEO	2015	[53]
Gonets SS (Roscosmos)	11	Mini	LEO	2014	[54]
SpaceX	4425	Mini	LEO	2024	[55]
Telesat	117		LEO	2021	[56]
BlackSky Global	60	Micro	LEO	2021	[57]
SPIRE Global	175	Nano	LEO	2020	[58]
Planet Labs	5		LEO	2008	[59]
Planet Labs	12	Nano	LEO	2015	[59]
Planet Labs	20	Nano	LEO	2016	[59]
Planet Labs	12	Nano	LEO	2016	[59]
Planet Labs	48	Nano	LEO	2017	[60]
Planet Labs (Terra Bella)	15	Micro	LEO	2017	[61]
Kepler Communications, Inc.	140	Nano	LEO	2022	[62]
Kineis	25	Micro	LEO	2022	[63]
ExactEarth	67	Nano	LEO	2018	[64]
Planet Labs	88	Nano	LEO	2017	[65]
Planet Labs	20	Nano	LEO	2019	[66]
Astro Digital	?	Micro	LEO	?	[67]
BRITE partners	5	Nano		2014	[68]
GHGSat, Inc.	3	Micro		2020	[69]
Satellogic	60	Micro	LEO	2020	[70]
Space View	16	Medium	LEO	2022	[71]
CASIC	156		LEO	2025	[72]
Leosat (Thales Alenia)	108	Large	LEO	*	[73]
Sky and Space Global	200	Nano	LEO	2020	[74]
GeoOptics	24	Nano	LEO	?	[75]
NOAA	12	mini	LEO	2020	[76]
PlanetIQ	18	Micro	LEO	2020	[77]
Zhuhai Orbita Control Engineering Ltd.	34	Micro	LEO	2020	[78]
Canon	100	Micro	LEO	?	[79]
Helios Wire	28	Micro	LEO	2023	[80]
Swarm Technologies	100	Pico		?	[81]
Iceye (BridgeSat)	18	Micro	LEO	2020	[82]
Analitical Space	?		LEO	?	[83]
Hiber	48	Nano	LEO	?	[84]
Fleet Space	100	Nano	LEO	2022	[85]
Audacy	3		MEO	2020	[86]
ELSE	64	Nano	LEO	2021	[87]
AISTech	102	Nano	LEO	?	[88]
AISTech	18	Nano	LEO	?	[88]
HawkEye360	21		LEO	?	[89]
Axelspace	50	Micro	LEO	2022	[90]
Capella Space	36	Micro	LEO	?	[91]
Karten Space	?	Nano	LEO	?	[92]
UnseenLabs	?		LEO	?	[93]
NSLComm	60	Nano	LEO	?	[94]
EightyLEO	?	Mini	LEO	2022	[95]
UrtheCast	24		LEO	2021	[96]
Orbital Micro System	40	Micro	LEO	?	[97]
Lacuna Space	32	Nano	LEO	?	[98]
Hera Systems	50		LEO	?	[99]
CASC (xinwei)	300		LEO	2025	[100]
SRT Marine	?		LEO	*	[101]
SatRevolution	1024	Nano	LEO	2026	[102]

Number of active satellites from 1957 to 2020

ALTER TECHNOLOGY

Company	No. Sats	Sats Size	Orbit	Year (Operative)	Reference
Commsat Technology Development Co. Ltd.	72		LEO	2022	[103]
Aerial and Maritime	80	Nano	LEO	2021	[104]
Harris	12	Nano	LEO	?	[105]
Earth-i	15	Mini	LEO	?	[106]
LinkSure Network	272		LEO	2026	[107]
Synspective	25	Mini	LEO	?	[108]
Space Systems Engineering Ukraine	?			?	[109]
Astrome	200	Mini	LEO	2023	[110]
Cloud Constellation Corp.	10		LEO	?	[111]
Transcelestial	?	Nano	LEO	?	[112]
Kleos Space	4		LEO	2019	[113]
HyperSat	6	Micro	LEO	*	[114]
Galaxy space	1000		LEO	?	[115]
ChinaRS	10	Micro	LEO	2021	[116]
Laser fleet	?		LEO	2022	[117]
XpressSAR	4			2022	[118]
Orbital oracle Technologies	100	Nano	LEO	2024	[119]
Methera Global	16		MEO	2022	[120]
Trident Space	48	Mini	LEO	2026	[121]
VEOWARE	?		LEO	2022	[122]
Umbra Lab	12		LEO	?	[123]
EarthNow	?		LEO	?	[124]
OQ Technology	?	Nano		?	[125]

© Aerospace 2020, 7, 133

Company	No. Sats	Sats Size	Orbit	Year (Operative)	Reference
Tekever	12	Micro	LEO	?	[126]
KLEO Connect	300		LEO	?	[127]
NorStar NorthStar	40	Medium		2021	[128]
Laser Light	12		MEO	2020	[129]
Koolock	?			?	[130]
ROSCOSMOS	10			2023	[131]
Hypercubes	?	Nano		?	[132]
ROSCOSMOS	288		LEO	2025	[133]
B612 Foundation	?	Micro		?	[134]
NASA	8	Micro	LEO	2017	[135]
CG Satellite	60		LEO	2020	[136]
Amazon	3236		LEO	?	[7]
Viasat	20		MEO	*	[13]
Iridium Inc.	66		LEO	2000	[11]
Boing	2956			*	[9]
Samsung	4600		LEO	*	[9]
Yaliny	135			*	[9]
Globalstart inc.	48		LEO	1999	[10]
OmniEarth	18		LEO	*	[137]
COMMStellation	72	Micro	LEO	*	[138]
Myriota	50	Nano	LEO	?	[139]
ADASpace	192		LEO	2021	[140]
Ubiquitilink	24			2021	[141]
ZeroG Lab	132		LEO	?	[142]
Stara Space	?	Nano	LEO	?	[143]
Hyperion	?	Nano	LEO	?	[144]
Horizon Technologies	10	Nano	LEO	?	[145]
SpaceFab.US	16	Nano		?	[146]
HEO Robotics	12	Nano	HEO	?	[147]
Artemis Space	?	Nano		?	[148]
Pixxel	?	Nano	?	?	[149]
US space Force	75	Large	MEO	1993	[150]
VKS	24	Large	MEO	1995	[151]
ESA	30	Medium	MEO	2020	[152]
CNSA	35	Large	MEO	2020	[153]

Many different technologies

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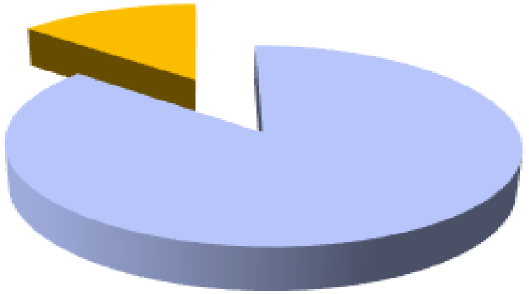
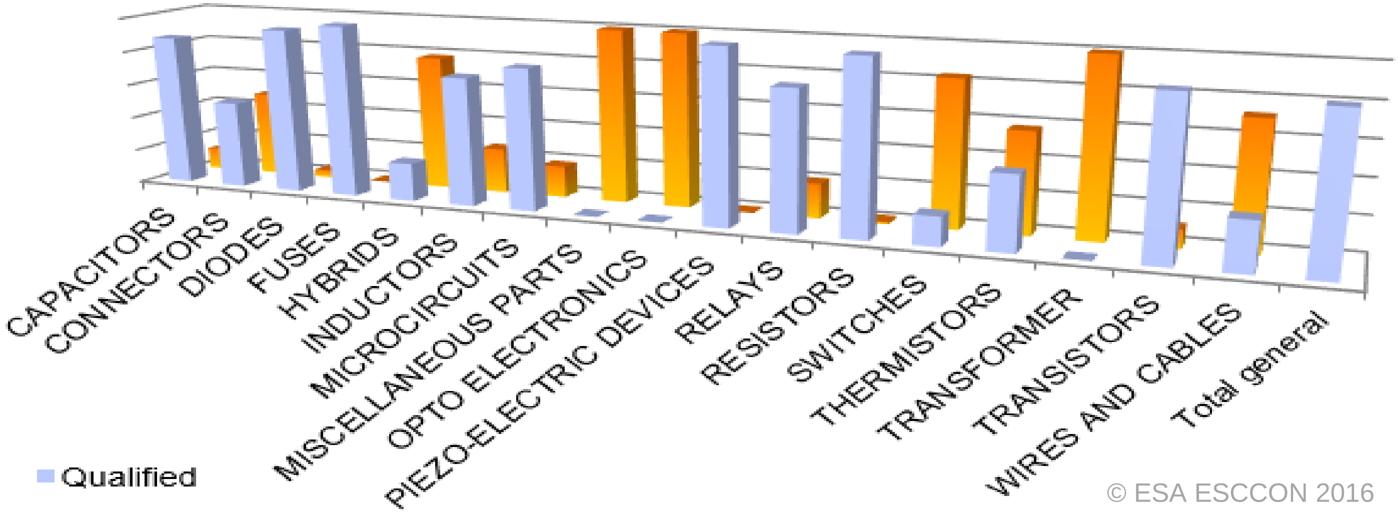
STATISTIC

- 3769 line items procured for FM

Qualified	Not Qualified
86.26%	13.74%





© ESA ESCCON 2016

	ESCC	MIL	NOT QUALIFIED
CAPACITORS	391	197	83
CONNECTORS	123	2	123
DIODES	76	131	9
FUSES	1		
HYBRIDS		16	57
INDUCTORS	50	2	18
MICROCIRCUITS	39	358	88
MISCELLANEOUS PARTS			2
OPTO ELECTRONICS			29
PIEZO-ELECTRIC DEVICES	3		
RELAYS	4		1
RESISTORS	859	796	21
SWITCHES		1	5
THERMISTORS	12	2	19
TRANSFORMER			14
TRANSISTORS	107	70	21
WIRES AND CABLES	11		28
Total	1676	1575	518

Complex test sequence

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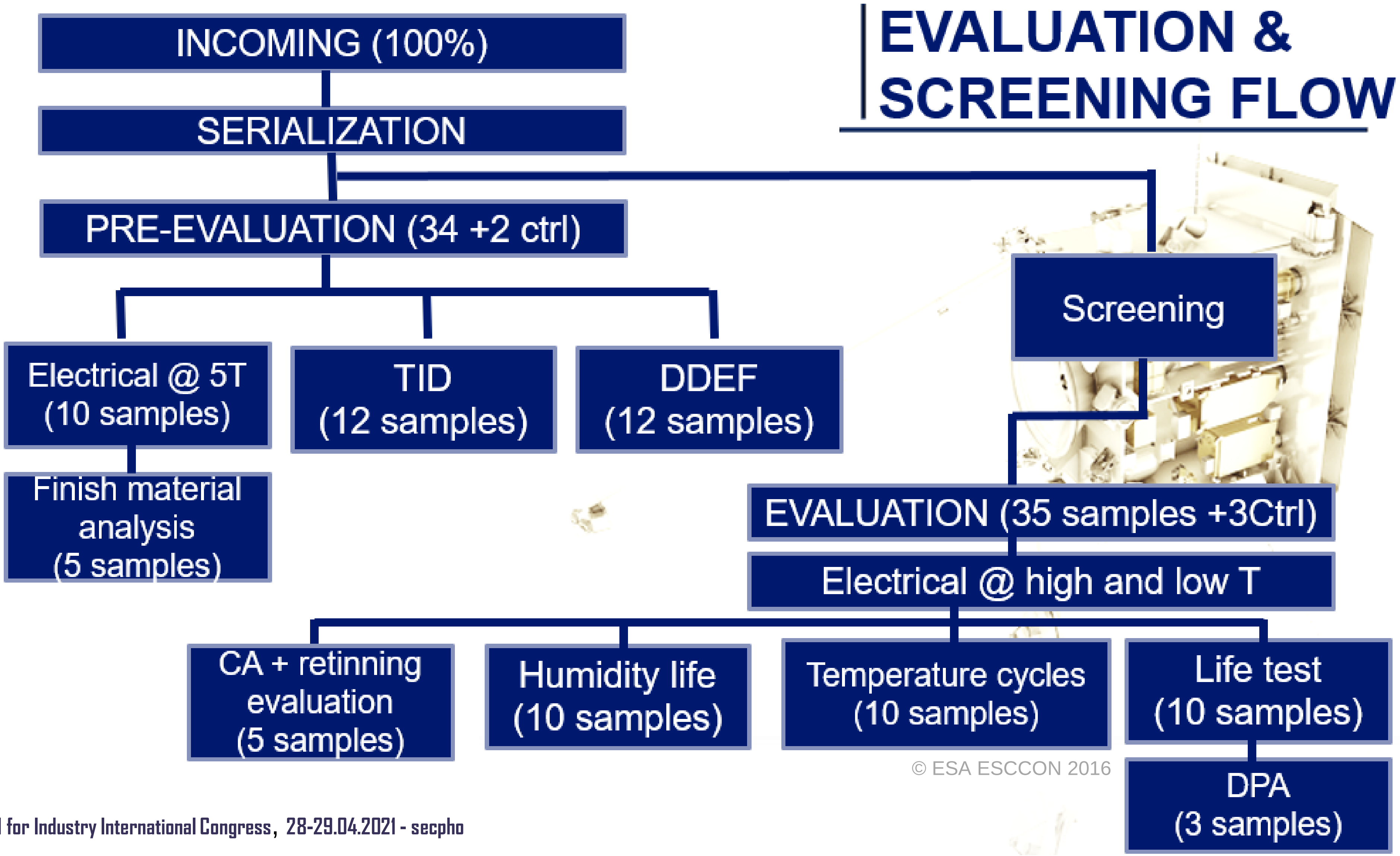

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Types of Earth orbit

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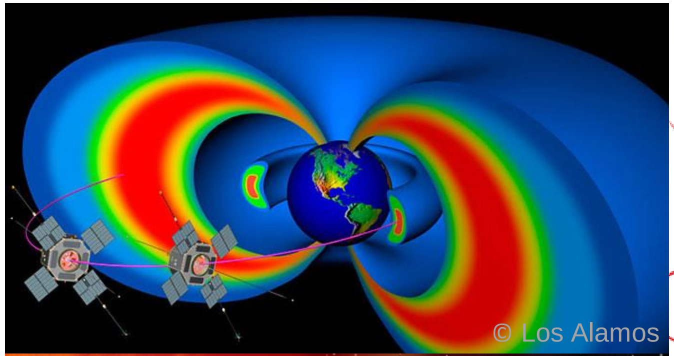
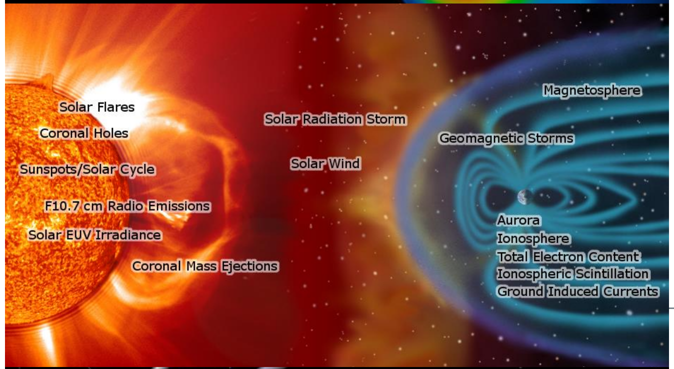
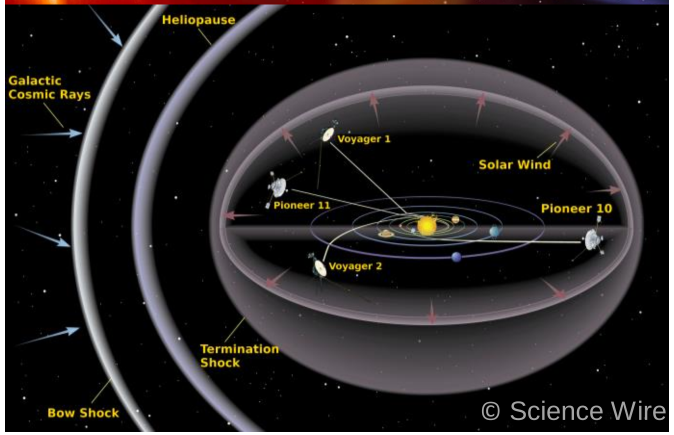
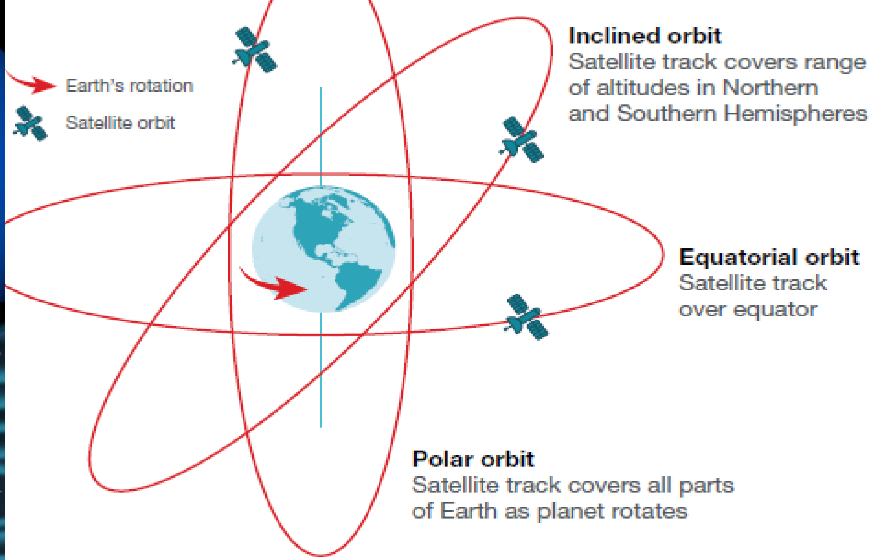


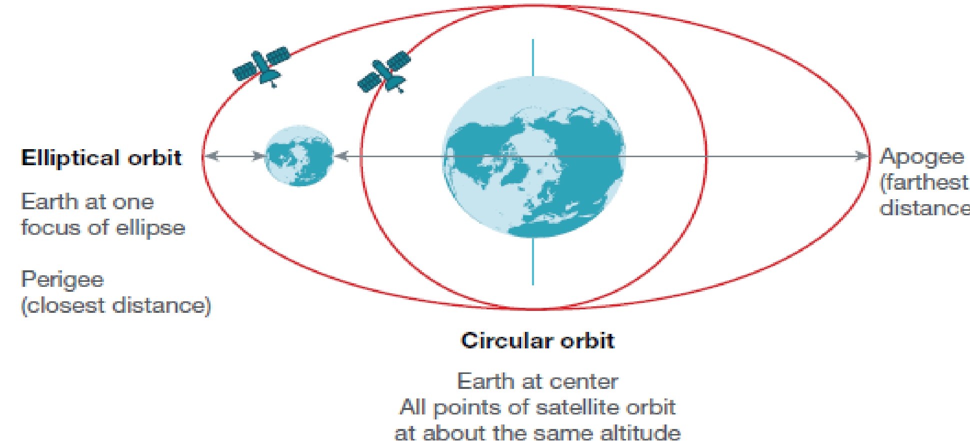




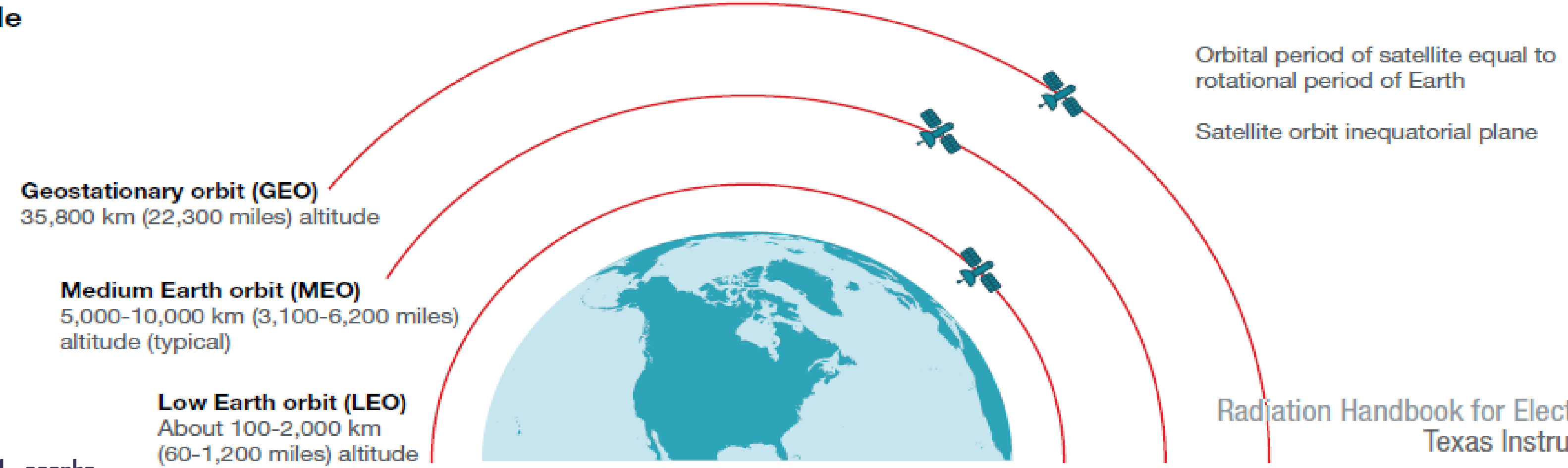
By inclination



By shape



By altitude



Radiation Handbook for Electronics
Texas Instruments

Types of radiation in space

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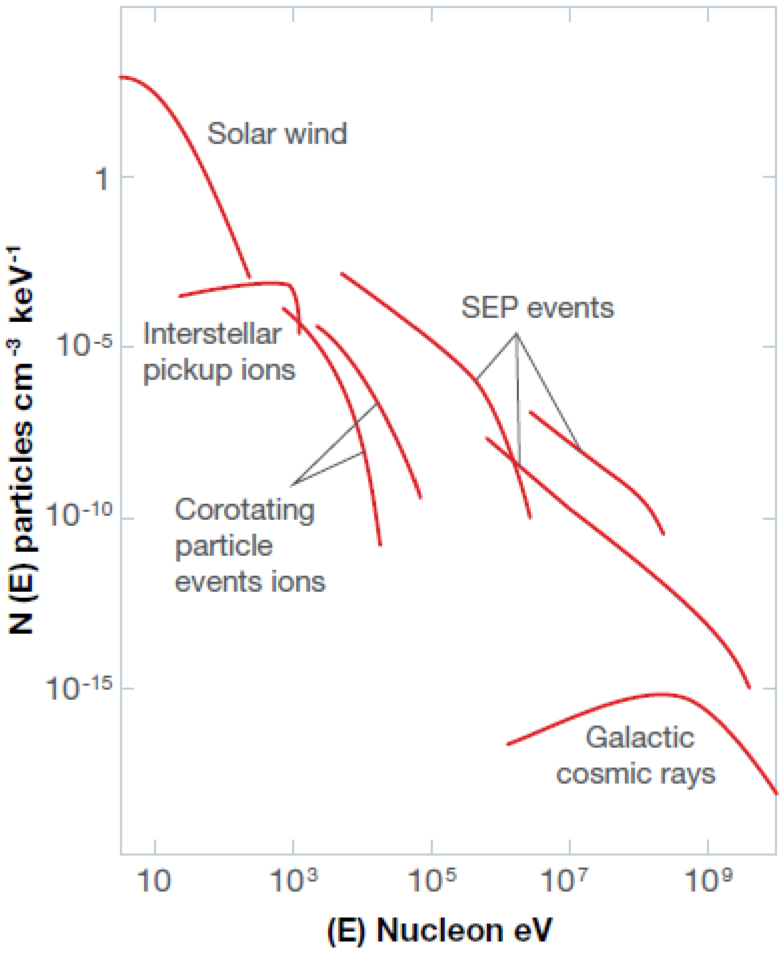

Figure 1-6. Differential proton flux as a function of proton energy for solar wind, SEPs and GCR distributions.

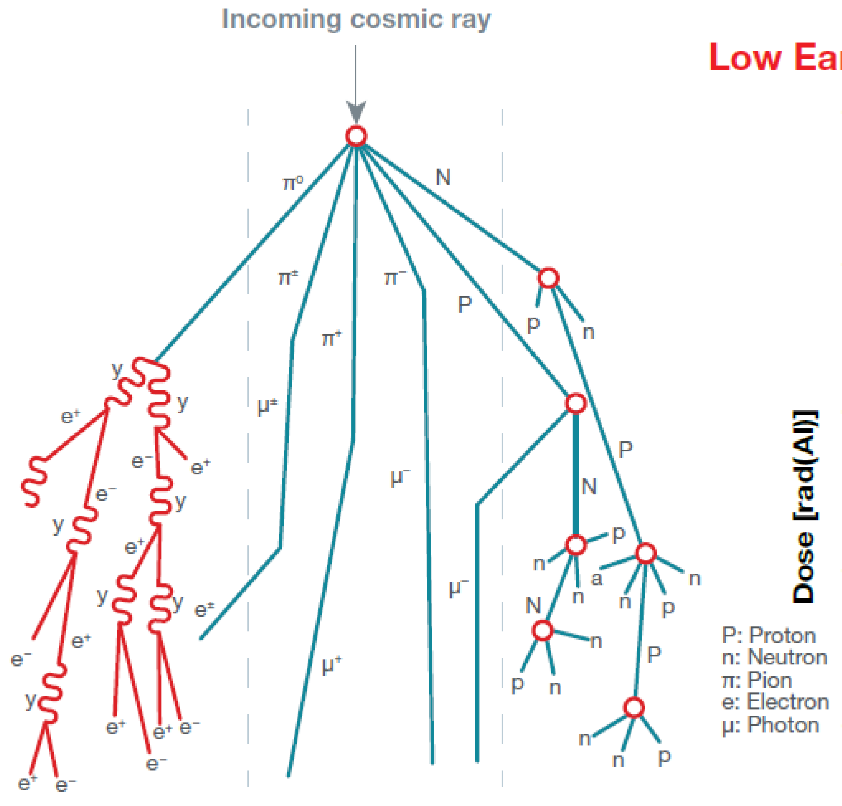

Figure 1-12. Particle cascade or "shower" created when a high-energy cosmic-ray proton interacts with a nitrogen or oxygen nucleus in the upper atmosphere.[27]

Image courtesy of International Business Machines Corp., © International Business Machines Corp.

Low Earth orbit

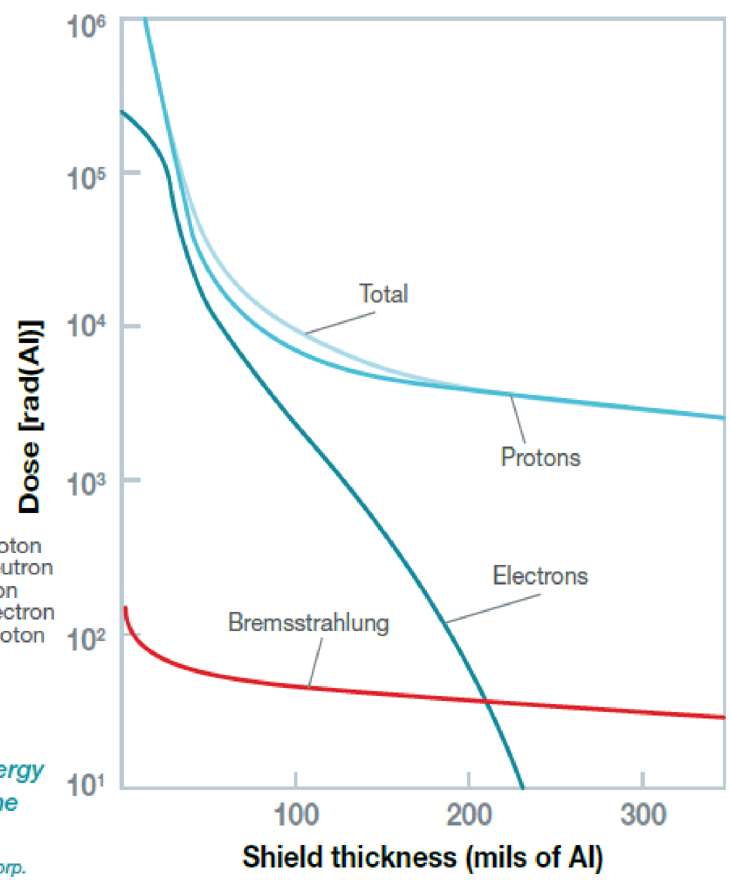

Figure 2-18. Plot of TID in low Earth orbit as a function of aluminum shielding thickness for three space radiations: protons, electrons and Bremsstrahlung.[38]

Radiation damages

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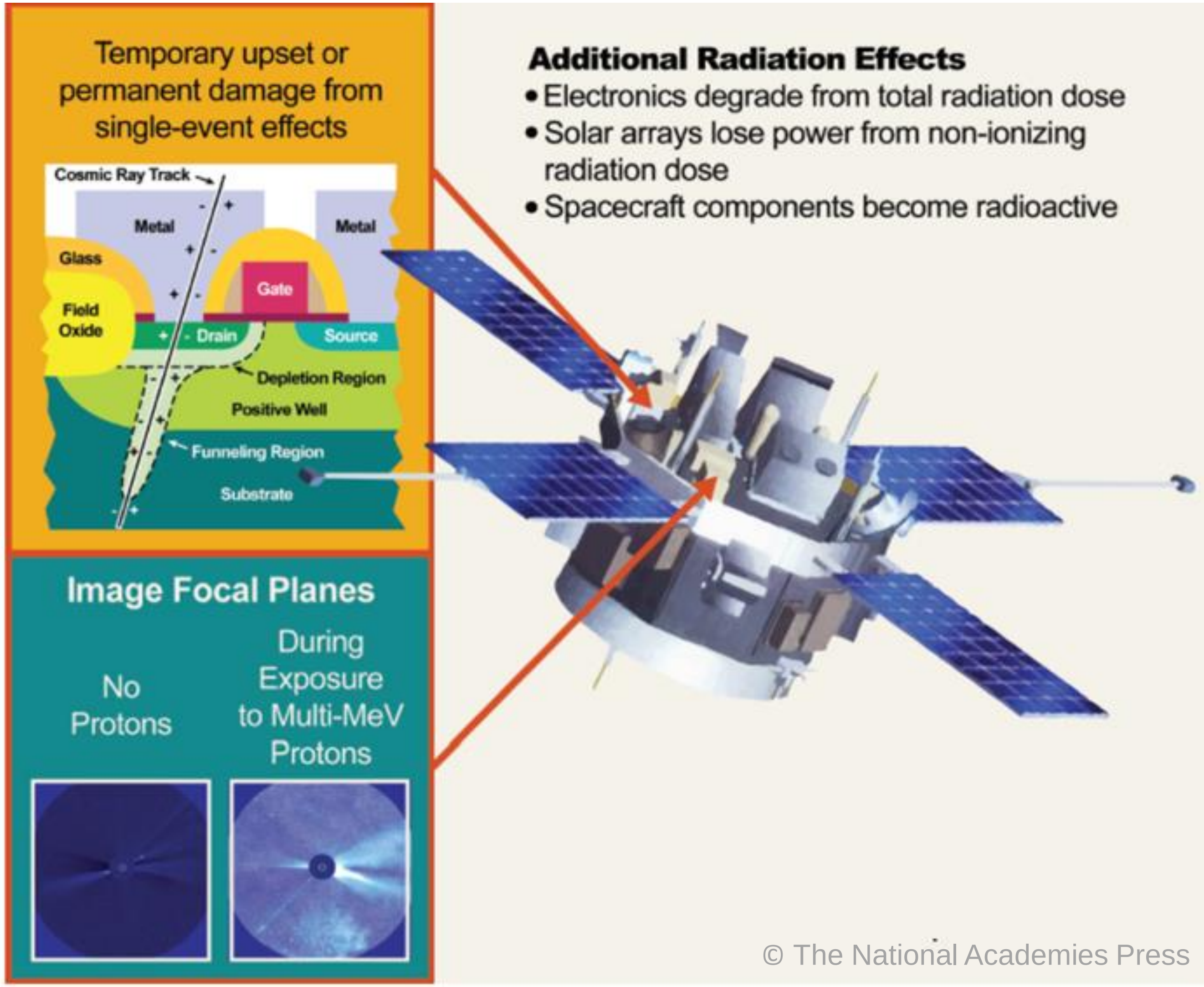

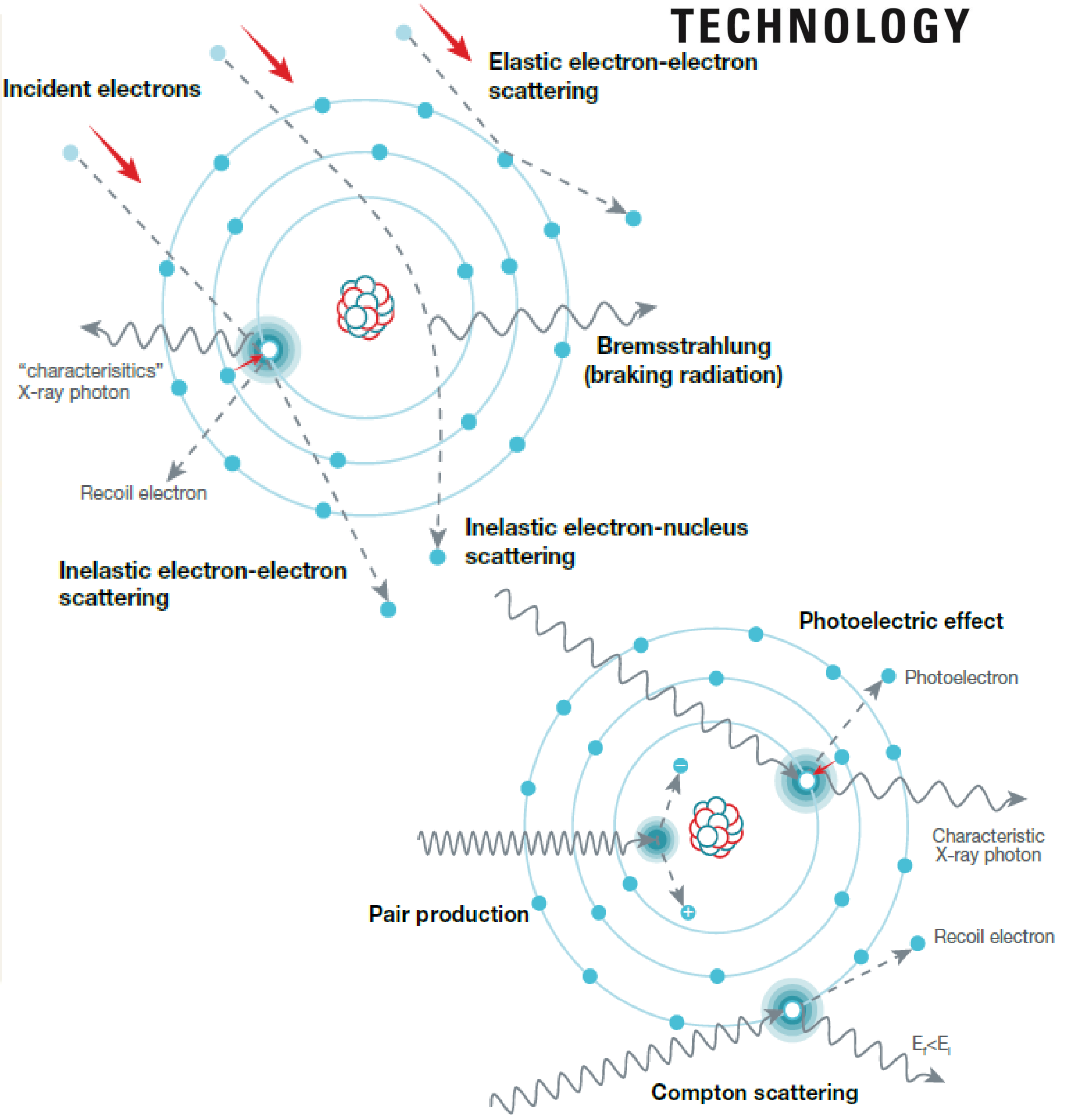

RAD LAB ™ OUR RADIATION LABORATORY

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RAD LAB ™ ACCREDITATIONS

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DEFENSE LOGISTICS AGENCY
LAND AND MARITIME
POST OFFICE BOX 3990
COLUMBUS, OH 43218-3990

October 28, 2014

Mr. Jose Andres Izquierdo
Alter Technology TUV Nord S.A.U.
C/ Tomas A. Edison 4
41092 Sevilla, Spain

-STD-750 and Mil-STD-883; FSC 5961 and FSC 5962;

findings from your facility audit
to perform testing

ENAC
Entidad Nacional de Acreditación
Otorga la presente / Grants this

Virtual Lab ™ – Concept

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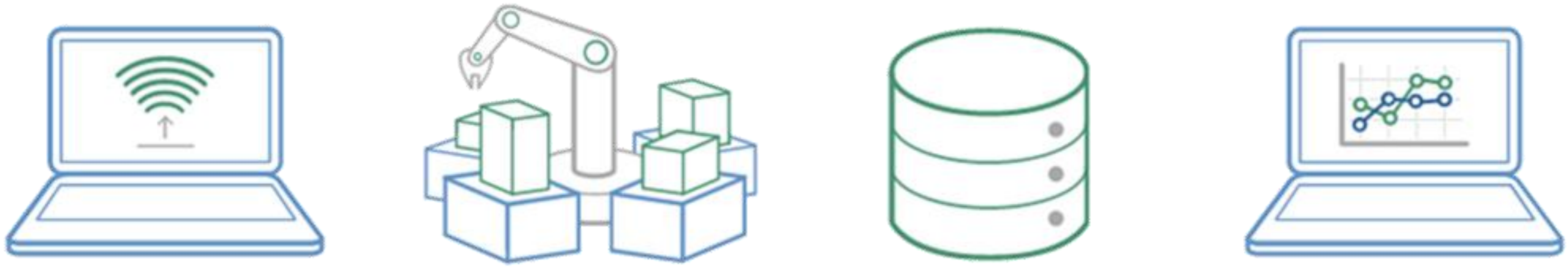
RUN EXPERIMENTS IN THE LAB FROM ANYWHERE IN THE WORLD



1 **DESIGN**

Design your tests over the web

2 **CONDUCT**

Virtual Lab conducts your tests

3 **EXPLORE**

Virtual Lab organizes your data into a smart data base

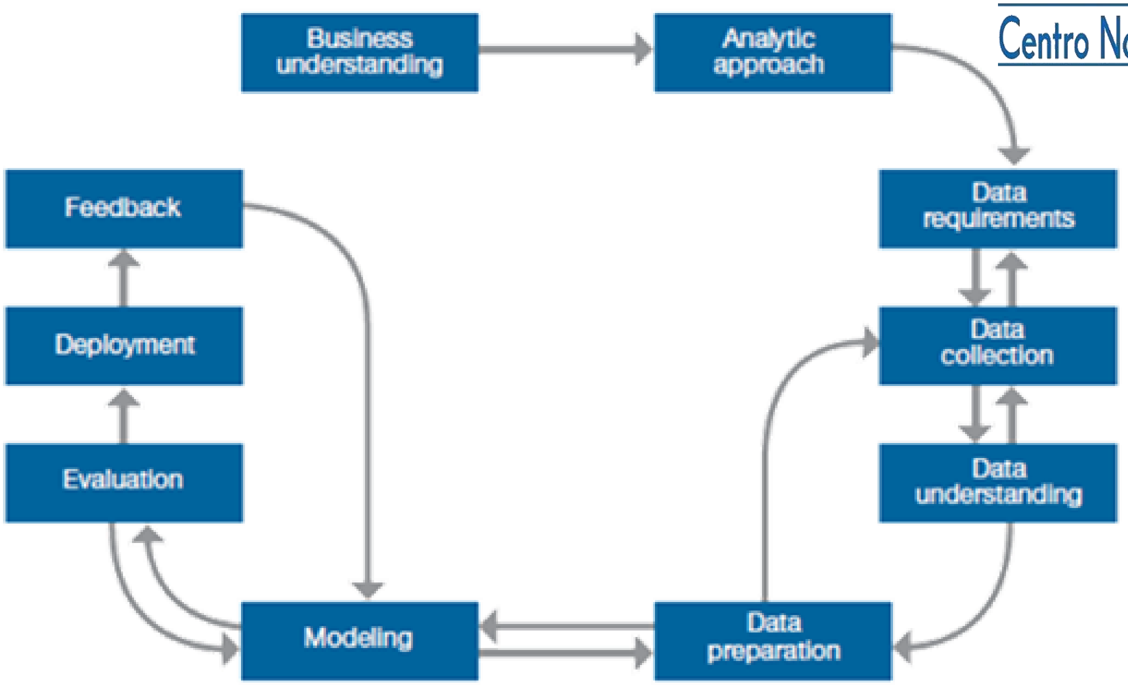
4 **ANALYZE**

DOEEET crunches and analyzes data

TÜV NORD GROUP
DIGITAL ACADEMY

CRISP-DM methodology

Cross Industry Standard Process for Data Mining



© Einar Karlsen, IBM

IBM Data Science Methodology

PRECEDER Tool – objectives

Predicción del Comportamiento Eléctrico de Dispositivos Electrónicos bajo Radiación

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CNA Centro Nacional de Aceleradores

(1) **Analyze the structure** of the currently available result set from irradiation tests conducted on electronic devices, mainly those used for space and/or high-energy projects.

(2) **Classify the data** to homogenize the structure of each group and be able to extract useful information that allows to feed the Automatic Learning software.

(3) Apply machine learning techniques, one of the branches of Artificial Intelligence, for **identifying the model** that best suits the needs of the project.

(4) **Obtain predictions** of the behavior of electronic devices subjected to radiation based on machine learning applied to tests already performed on other devices.

(5) Analyze the behavior of a small sample of devices to **check predictions** against experimental results.

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Proyecto 2020/00000158
FEDER Fondo Europeo de Desarrollo Regional
UNIÓN EUROPEA "Una manera de hacer Europa"

Supervised Learning

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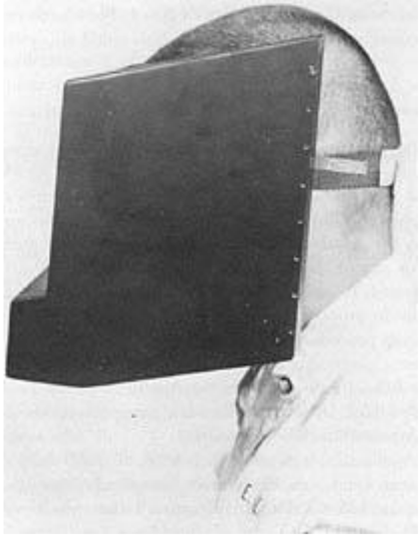
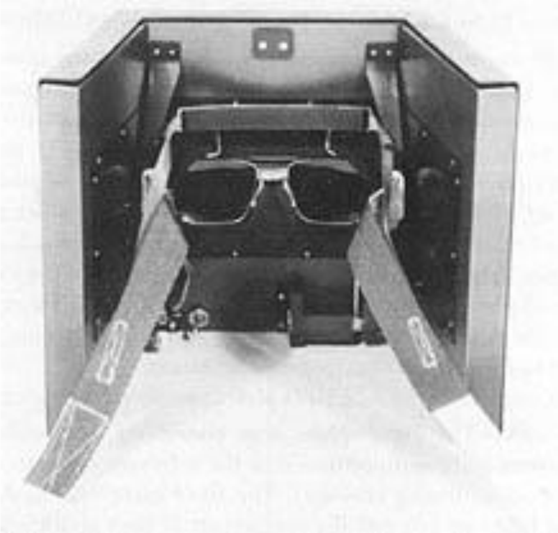
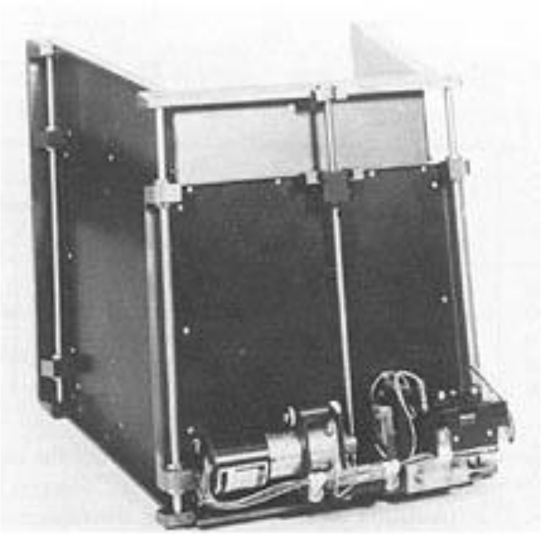
ALFMED experiment - Apollo Light Flash Moving Emulsion Detector



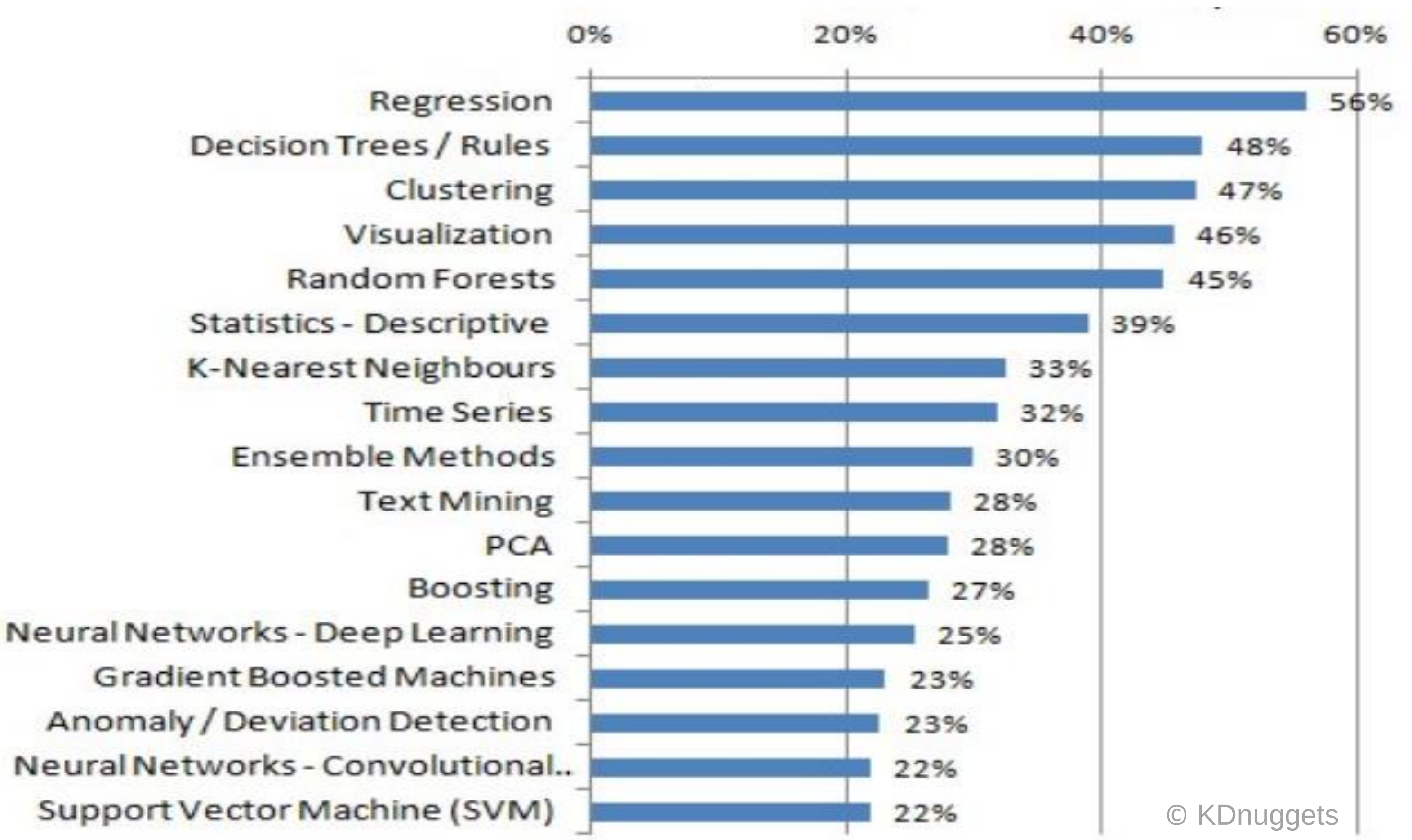




© NASA

Crewmembers of the **Apollo 11 mission** were the first astronauts to describe an unusual visual phenomenon associated with space flight. During transearth coast, both the Commander and the Lunar Module Pilot reported seeing **faint spots or flashes of light** when the cabin was dark and they had become dark-adapted.

Top Data Science Methods used in 2018-19



PRECEDER – Data understanding

Predicción del Comportamiento Eléctrico de Dispositivos Electrónicos bajo Radiación

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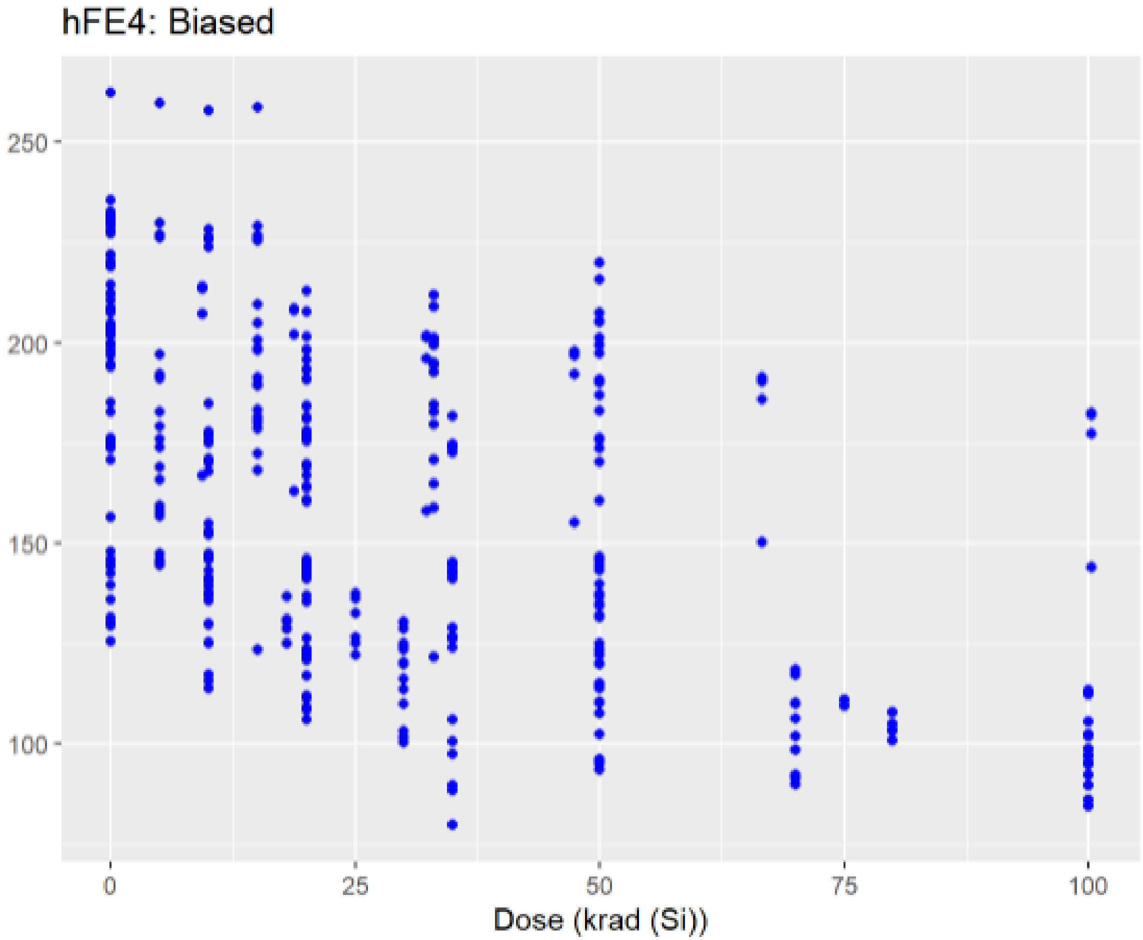
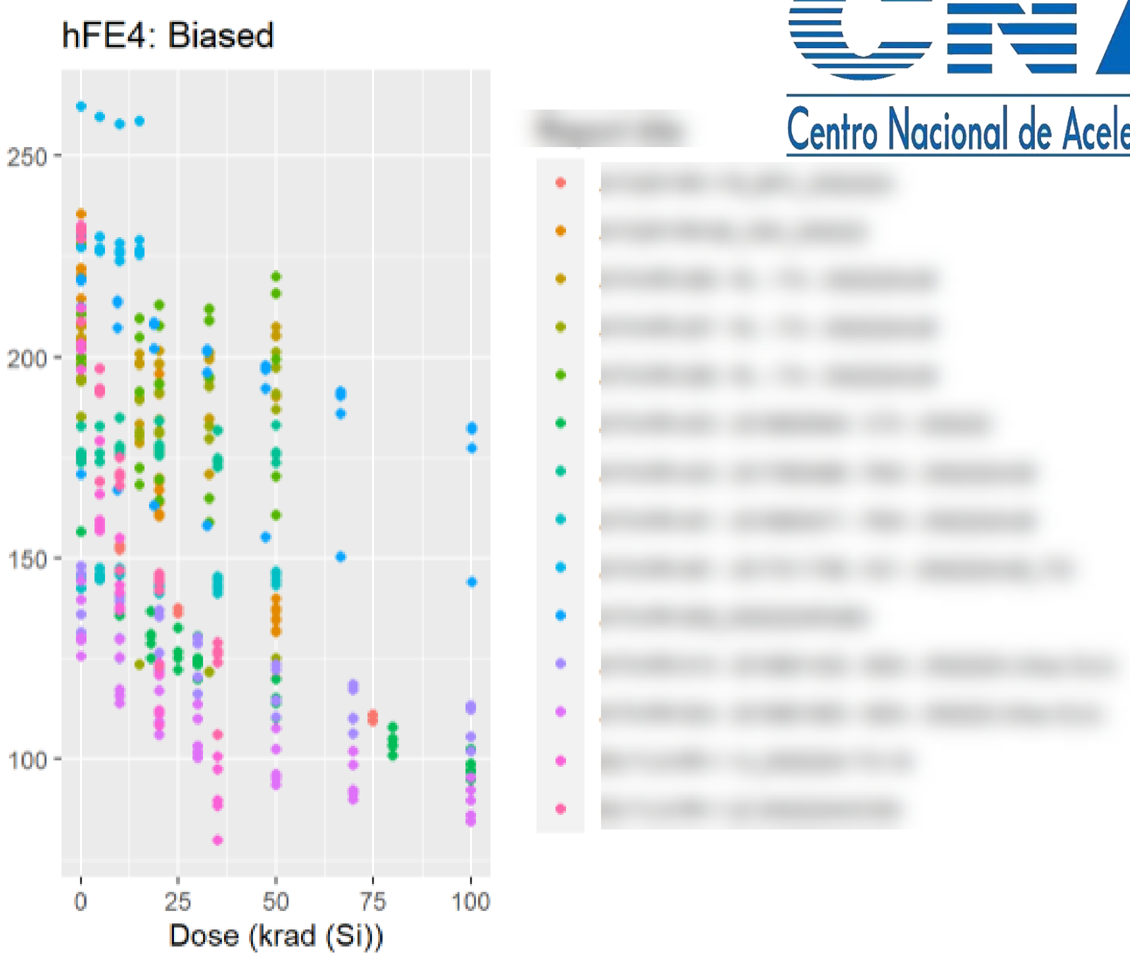
CNA Centro Nacional de Aceleradores





Virtual Lab

PRECEDER – Evaluation

Predicción del Comportamiento Eléctrico de Dispositivos Electrónicos bajo Radiación

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CNA Centro Nacional de Aceleradores

CERN

UNED

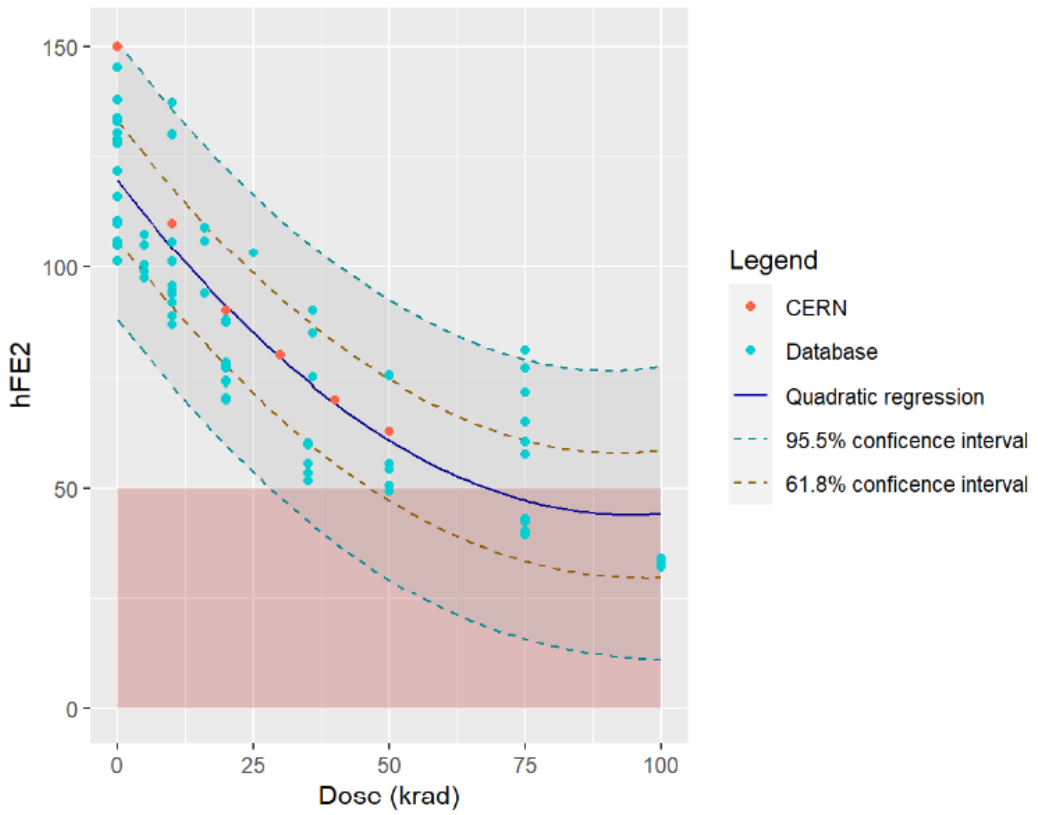

Fig. 3. Degradation of the h_{FE2} gain, measured at $I_C = 0.1$ mA, for the 2N3019 BJT while irradiated with biased condition.

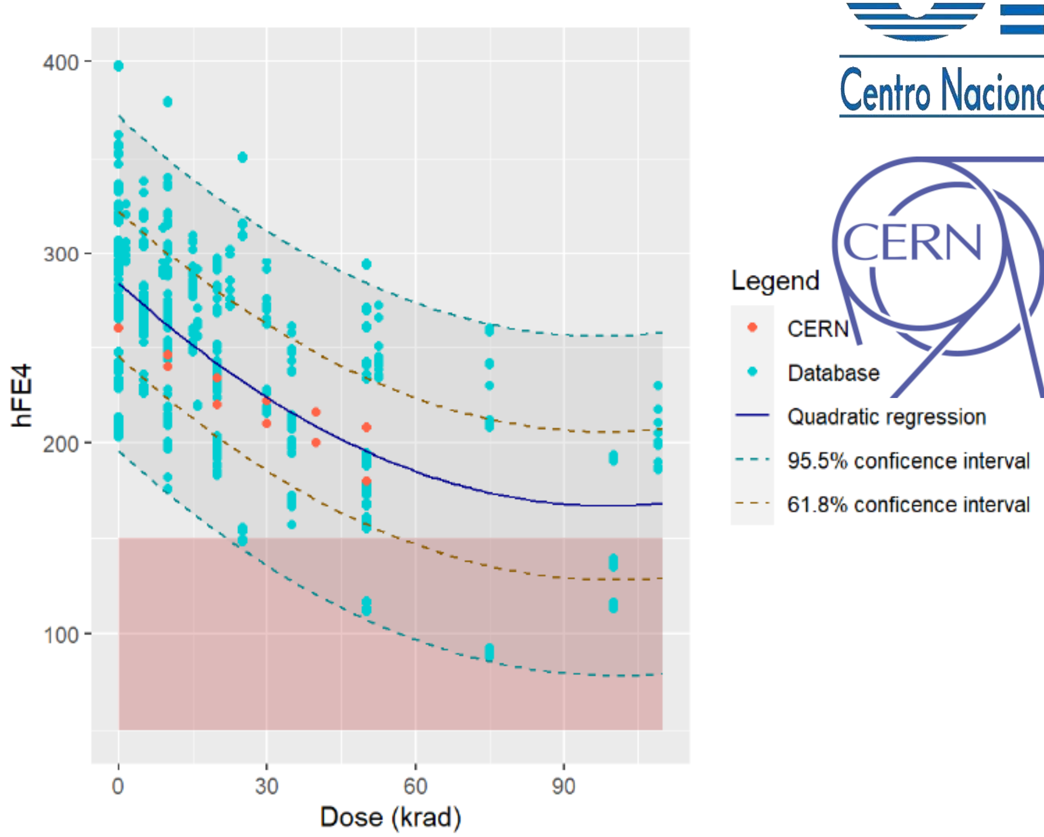

Fig. 4. Degradation of the h_{FE4} gain, measured at $I_C = 1$ mA, for the 2N3810 BJT while irradiated with biased condition.

Virtual Lab

Virtual Lab ™ – Predictions

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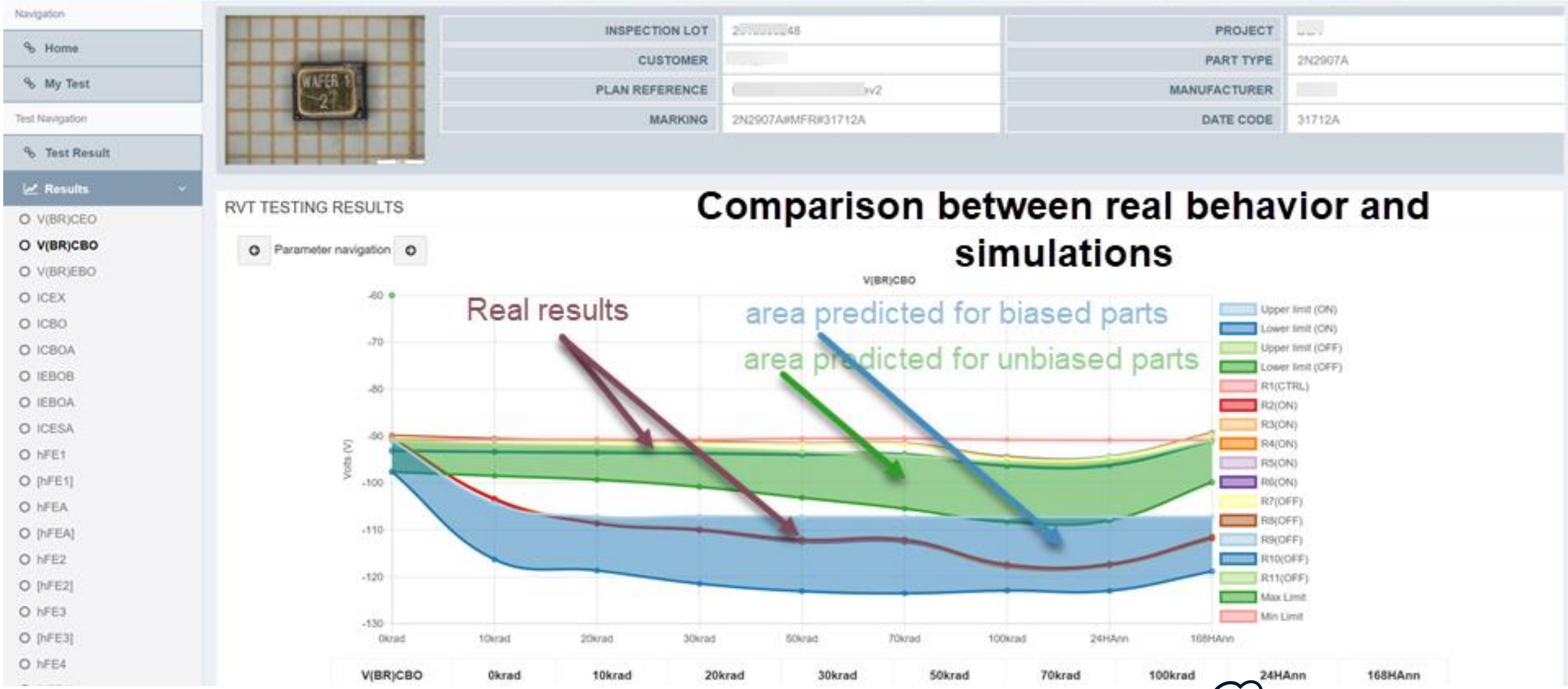
Predicción del Comportamiento Eléctrico de Dispositivos Electrónicos bajo Radiación



Virtual Lab

Virtual Lab ™ – Predictions

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Predicción del Comportamiento Eléctrico de Dispositivos Electrónicos bajo Radiación

PARAMETERS	SYMBOL	Limits PRE min	Limits PRE max	Limits POST min	Limits POST max	UNIT	Level 20 krad Value	Level 20 krad Ɛr	@ CONDITIONS
Collector to Base Cut-off Current	ICBO1	--	10000	--	10000	nA	1.253	±2.985	VCB=75 V
Emitter to Base Cut-off Current	IEBO1	--	10000	--	10000	nA	0.150	±2.383	VEB=6 V
Collector to Base Cut-off Current	ICBO2	--	10	--	10	nA	0.983	±2.748	VCB=60 V
Emitter to Base Cut-off Current	IEBO2	--	10	--	10	nA	0.100	±2.377	VEB=4 V
Forward Current Transfer Ratio	hFE1	50	--	50	--	--	133.759	±0.791	VCE=10 V, IC=0.1 mA
Forward Current Transfer Ratio	hFE2	75	325	75	325	--	154.738	±0.658	VCE=10 V, IC=1.0 mA
Forward Current Transfer Ratio	hFE3	100	--	100	--	--	173.024	±0.554	VCE=10 V, IC=10 mA
Collector-emitter saturation voltage	VCE(sat)1	--	300	--	300	mV	142.256	±1.716	IC=150 mA; IB=15 mA
Base-emitter saturation voltage	VBE(sat)1	600	1200	600	1200	mV	850.406	±0.068	IC=150 mA; IB=15 mA

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Virtual Lab ™ – Innovation Award 2019

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erster Innovation Award aus Anlass des Jubiläums vergeben

Der erste TÜV Nord Group Innovation Award ist vergeben – das Virtual Lab von Alter Technology und TÜV Nord Systems setzte sich in einem Kopf-an-Kopf-Rennen gegen zahlreiche Mitbewerber durch.

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AI in Space – more to come

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1. **Autonomous landing**, rendezvous, and docking capabilities.
2. Probes exploring the far regions of the Solar System has a **communication delay is between 6-42 minutes** to travel to Mars and back and over an hour beyond Jupiter.
3. Machine learning (ML) algorithms can identify debris in space so that decisions on **collision avoidance** can be anticipated and avoided.
4. Rovers can **navigate around obstacles** independently of human control and intervention.
5. Identify instances whereby complex navigational calculations can be made in real-time by the probe to **react to conditions difficult to predict from Earth** pre-mission.
6. Predictive models can be created with AI which allow space actors to more **effectively assess, prioritise, and manage**.
7. …and many many more.

Virtual Lab

Centro Nacional de Aceleradores

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Our **Lab** and **Knowledge** at your fingertips

Thank you

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