



60  
years

FEET ON THE GROUND

EYES ON THE SKY





# ESO AND FRENCH INDUSTRY

M. FERRARI (CNRS/INSU)

ESO 60-YEARS  
2022, NOVEMBER 3RD







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THIS IS NOT A COMPLETE DESCRIPTION OF ALL THE PARTICIPATIONS OF THE FRENCH INDUSTRY IN ESO PROGRAMMES, BUT RATHER HIGHLIGHTS COVERING THE MAJOR IMPLICATIONS.

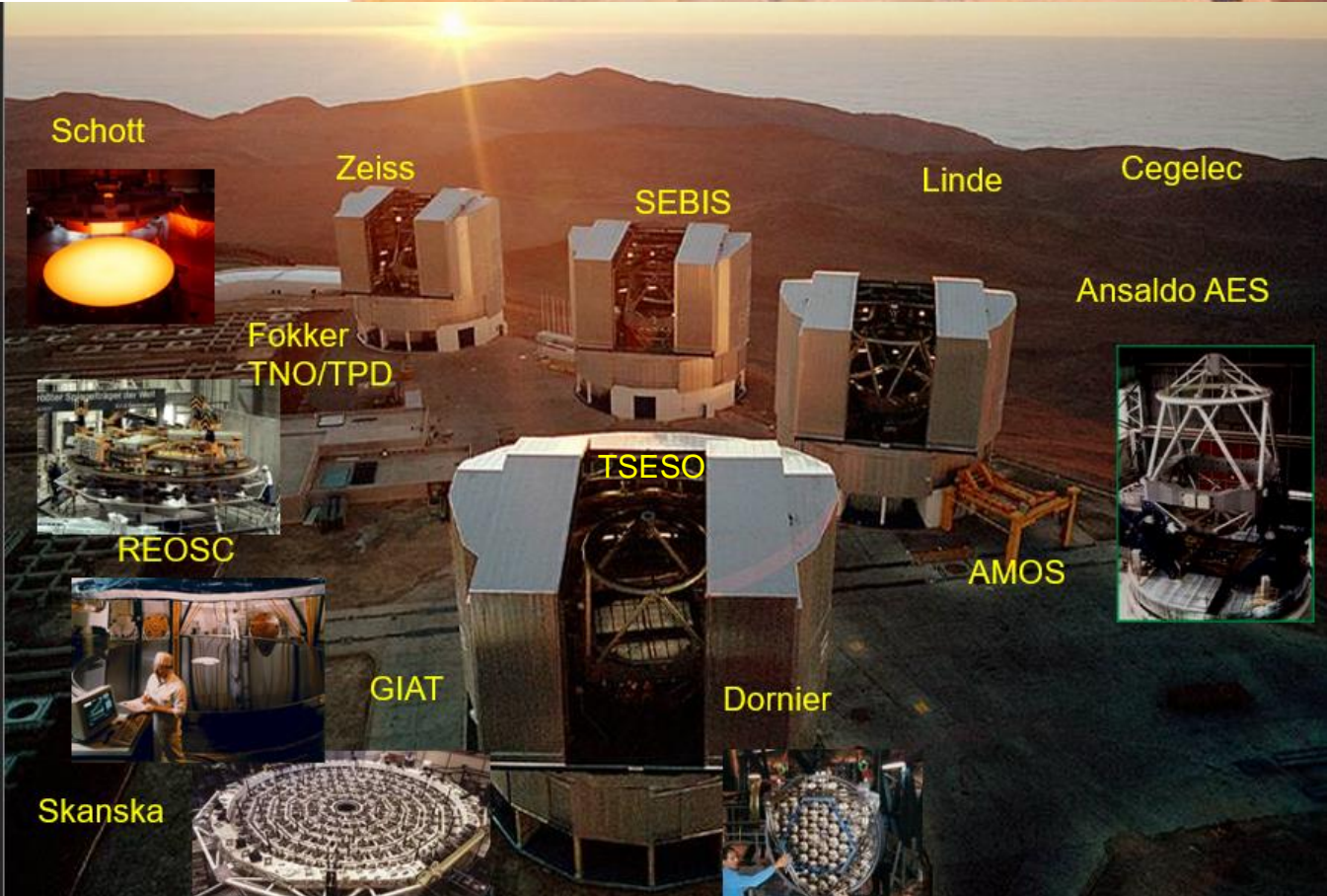
SORRY IF I FORGOT YOUR FAVORITE COMPANY OR INSTRUMENT BUT COME TO SEE ME AFTER...







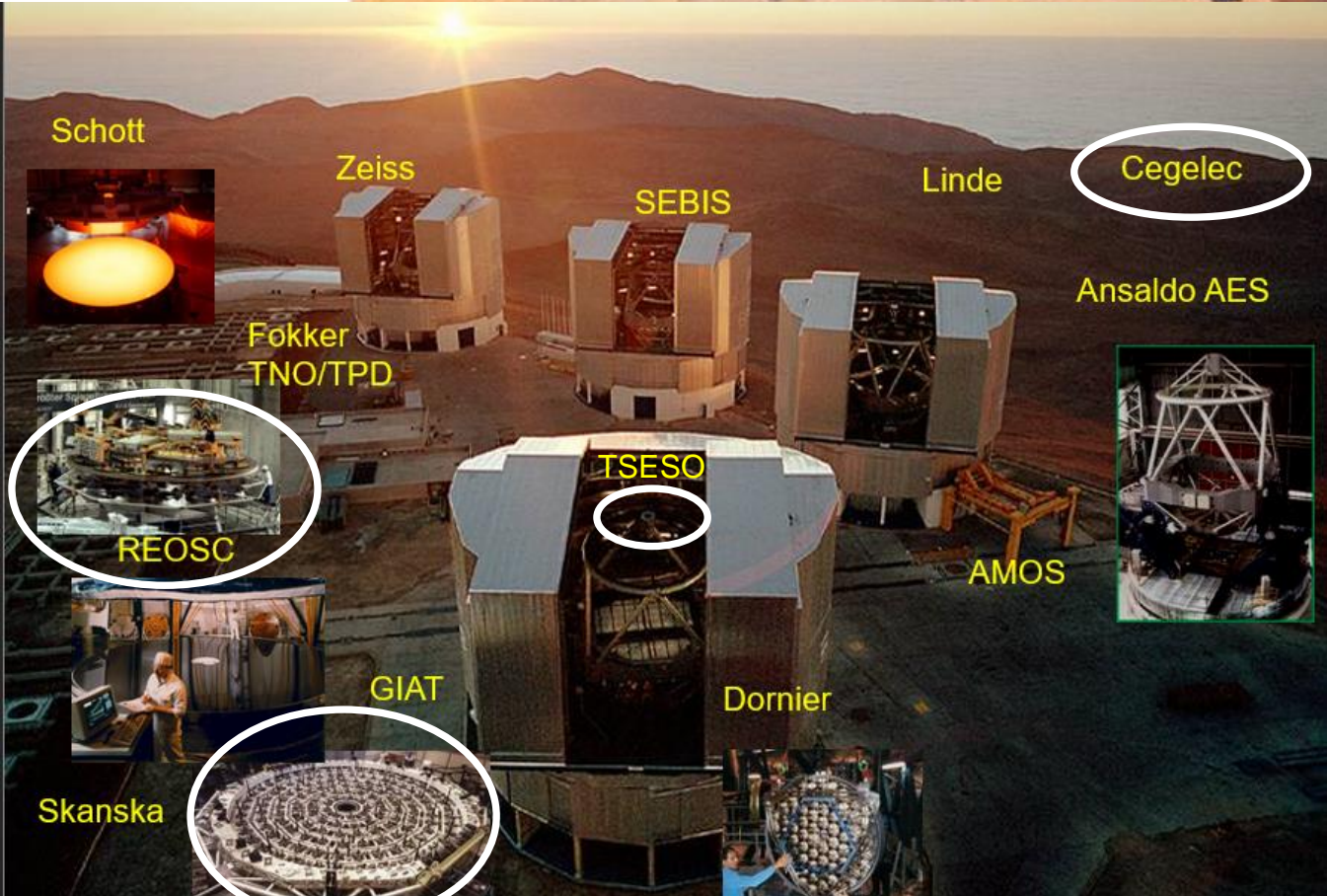
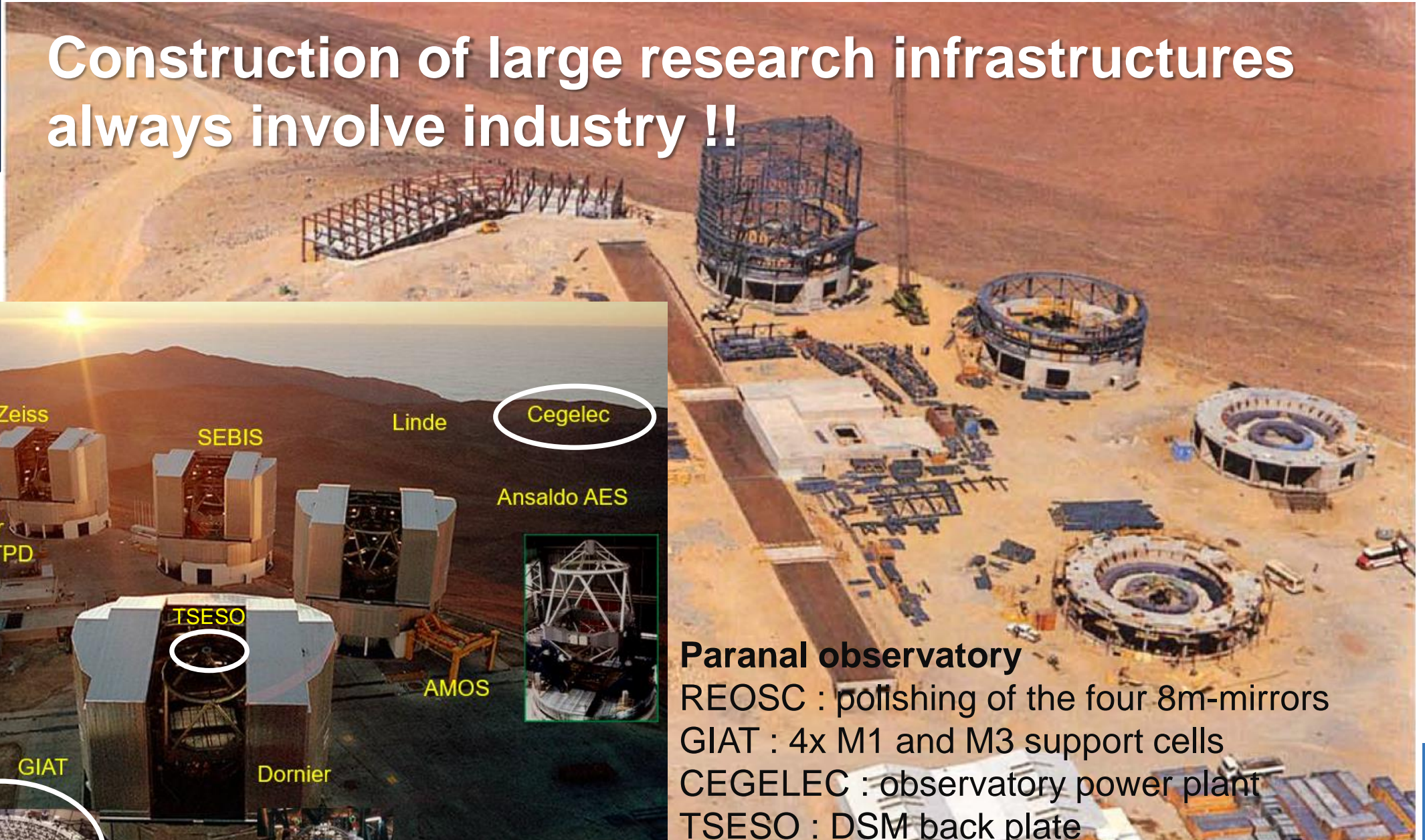
# Construction of large research infrastructures always involve industry !!







# Construction of large research infrastructures always involve industry !!



## Paranal observatory

- REOSC : polishing of the four 8m-mirrors
- GIAT : 4x M1 and M3 support cells
- CEGELEC : observatory power plant
- TSESO : DSM back plate
- and many many more contributions ...





# Construction of large research infrastructures always involve industry !!



THALES : Lead of the AEM international consortium of French, Italian and German companies.

Responsible for the manufacturing and delivery of the 25 European ALMA antennas.







# Construction of large research infrastructures always involve industry !!

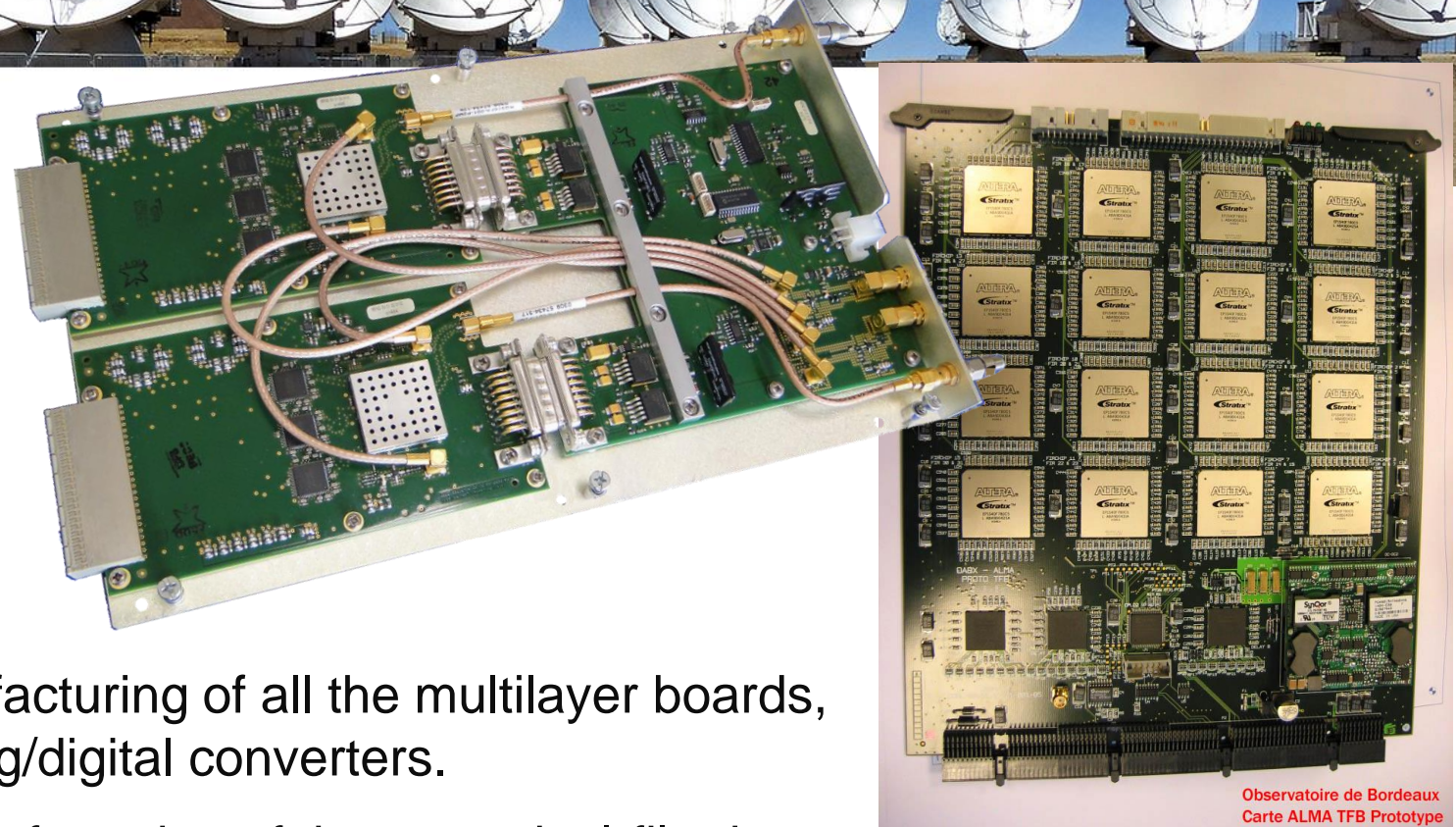


FABRICANT DE CARTES  
ET PRODUITS  
ÉLECTRONIQUES PROFESSIONNELS

STMicroelectronics was responsible for the manufacturing of new  $\mu$ chips completely developed by LAB.

FEDD was responsible for the manufacturing of all the multilayer boards, with the STMicro chips, for the analog/digital converters.

FEDD was also selected for the manufacturing of the numerical-filtering boards of the ALMA correlators, with 16 FPGA each.



Observatoire de Bordeaux  
Carte ALMA TFB Prototype



Almost 1,000 complex electronics boards in total !



# THE FRENCH INDUSTRY IN THE ESO PROGRAM

Beyond these well-know examples of large companies acting in the construction of the ESO observatories...

Involvement of all types of companies, for the observatories, the telescopes and their instrumentation.

- Large groups: SAFRAN, THALES, Air Liquide,
- Intermediate-sized companies : CILAS, Bertin-Winlight, SDMS, ..

And a Galaxy of smaller and innovative companies !

- SMEs : AlpAO, First Light Imaging, Le Verre Fluoré, Fogale Nanotech,  
...



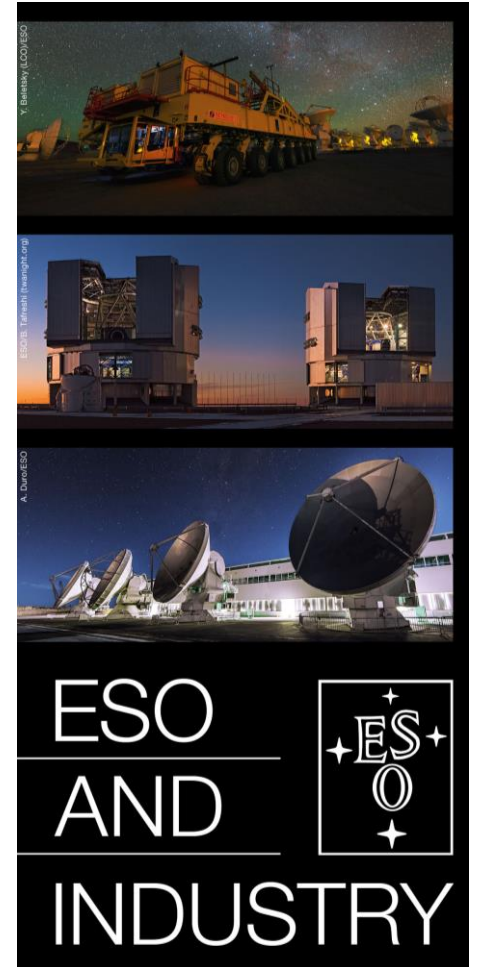


# THE FRENCH INDUSTRY IN THE ESO PROGRAM

Several areas of expertise where French companies are leaders or at the forefront of technologies.

- Optics (mirrors, deformable mirrors, instruments..)
- Adaptive optics, Spectroscopy, Photonics,
- Opto-mechanics,
- Metrology,
- Detectors, Imaging systems,
- Cryogenics,
- Computing, Data processing,
- Electronics,
- Manufacturing,
- Materials,
- Equipments and infrastructure,
- ...

In perfect match with the instrumental expertise of the french laboratories (see K. Perraut talk)





# THE FRENCH INDUSTRY IN THE ESO PROGRAM

More than 80 companies were identified in 2020.

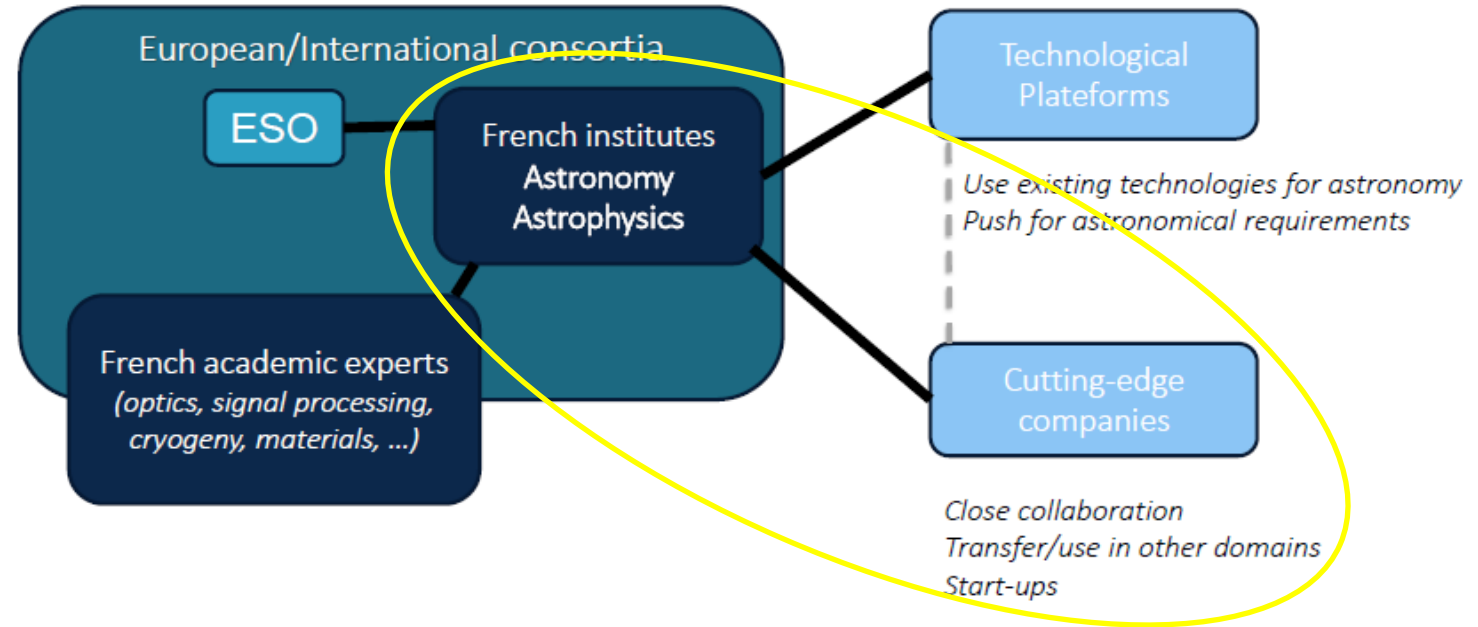




# A STRONG PARTNERSHIP WITH LABORATORIES

**Astronomical instrumentation is a powerful driver for innovation.**

**Both laboratories and industries contribute to new technologies  
TRLs increase, addressing new astrophysical questions...**



**Research/Industry collaboration takes all the possible ways : from co-development, to creation of Start-Ups or technological transfer and licensing of patents.**

**Two examples of companies that grew out of astronomical developments for ESO that are now at the forefront or leaders in their fields :**

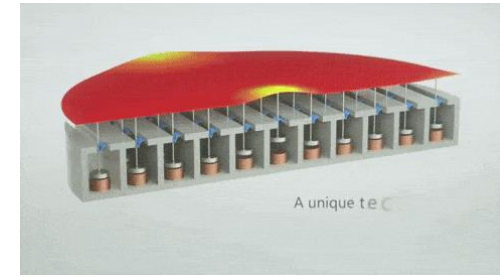


and





# DEFORMABLE MIRRORS FOR ADAPTIVE OPTICS



**Development of new deformable mirrors using electromagnetic actuators**

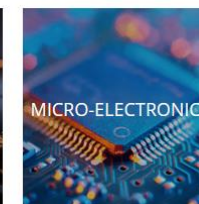
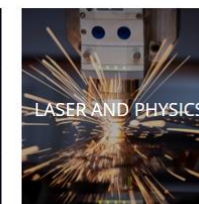
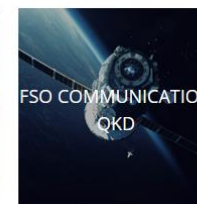
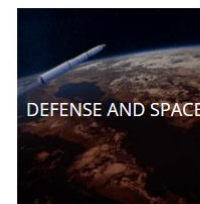
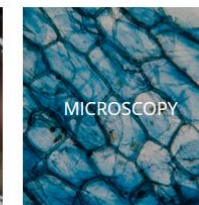
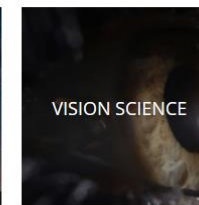
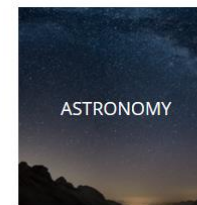
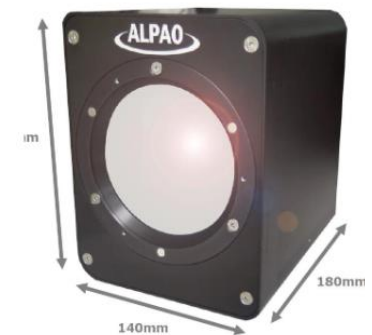
**Framework of the AOELT European Program (2000-2004)**

→ to prepare future instrumentation, secure another techno than piezo-stack arrays

**Creation of AlpAO, spin-off of the IPAG laboratory (ex. LAOG) in Grenoble**

**Today, one of the DMs (and AO systems) leaders in the world**

- Equipment of all VLT auxiliary telescopes AO systems
- Development contracts for compact DM and XAO DM for future VLT/ELT instrumentation
  - Foreseen use of AlpAO DMs on MAVIS, GRAVITY+, MICADO, HARMONI, ..
- DMs and associated systems sold to major observatories,
- Partnership with KECK observatory for new AO system
- From Astronomy to several new markets ...



## FAST LOW-NOISE LOW-LIGHT CAMERAS



**Development of new camera for AO wavefront sensors**

**Framework of the OPTICON European Program (2005-2011)**

→ to prepare future instrumentation (VLT-SPHERE), increasing performance

Development of the OCAM camera for the SPHERE SAXO WFS using E2V EMCCD

**Creation of First Light Imaging, spin-off of the LAM and IPAG laboratories**

**Today, (one of) the world leader(s) in fast low-noise Visible and IR cameras**

- Cameras sold to all major observatories and laboratories (ESO, Keck, Caltech, LBT, Subaru, ...)
- Use of various sensors from TeledyneE2V, LYNRED, Leonardo, etc..,
- Will provide WFS cameras for the ELT and ELT instruments
- An impressive catalog of cutting-edge products
- From Astronomy to several new markets ...



SCIENTIFIC AND INDUSTRIAL CAMERAS, TO MAKE THE INVISIBLE VISIBLE



See talk of Philippe GODEFROY

## Patent for Image Slicing between Winlight and CNRS

With strong expertise in imaging-spectrograph conception  
Winlight has been at the heart of the VLT MUSE instrument.

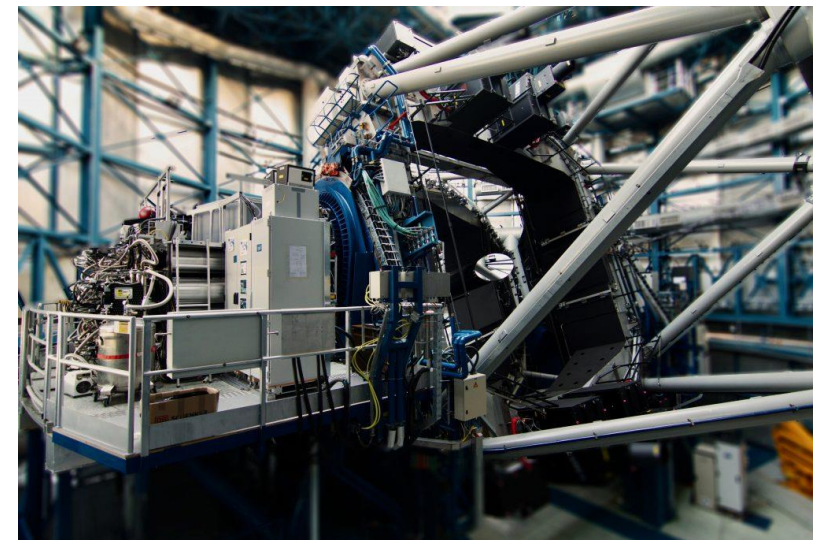
24 identical spectrographs working in parallel !!

Need to involve industry from the very beginning of the project

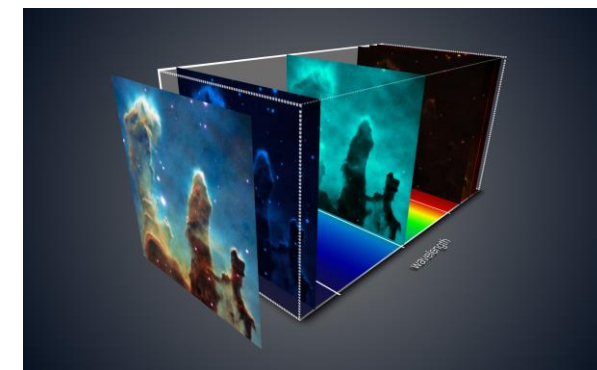
## Winlight produced for MUSE :

- 24 images-slicers systems and the 24 spectrographs  
→ A total of more the 2500 optical components !

**Since MUSE** : Involvement in ESO 4MOST instrument, but also in spectrographs for the Dark Energy Spectroscopic Instrument (DESI) at Kitt Peak, and the Prime Focus Spectrographs (PFS) for the SUBARU telescope....



MUSE instrument @UT4 © R. Bacon



3D data cube © MUSE/ESO

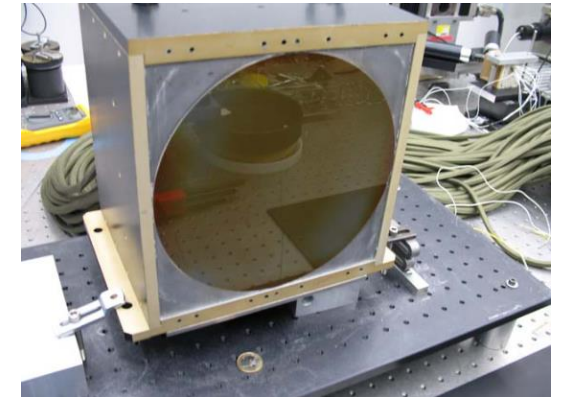
## Historical development of Deformable Mirror for AO

From military to the first astronomical system Come-On @ OHP (1989)

## Two technologies developed for/with ESO

- Stack Array Mirrors (SAM) for astronomy
- Bimorph or Monomorph Mirrors for astronomy, laser and space

→ SAM195 for NAOS, and high-order DM (1377 act.) for the VLT SPHERE instrument



SPHERE SAM DM with 1377 act. - © CILAS



## World leader in Stack Array and Bimorph technologies

Several contracts for all major observatory : GEMINI, KIS, SUBARU, GTC, TMT...

Major references for astronomy

Stack Array Mirror	Number of actuators	Pupil diameter
Woofer DM for Gemini Planet Imager	97	45 mm
DM for NAOS at VLT (ESO)	195	112 mm
High Order DM for Gregor Solar Telescope	256	50 mm
DM for AO at Gran Telescopio Canarias	373	140 mm
High Order DM for SPHERE at VLT (ESO)	1377	180 mm
Upcoming DM0 for TMT	3125	325 mm
Upcoming DM11 for TMT	4548	386 mm

...From 50 to 5000 actuators

Aperture  
386 mm



Prototype DM for the TMT observatory  
© CILAS

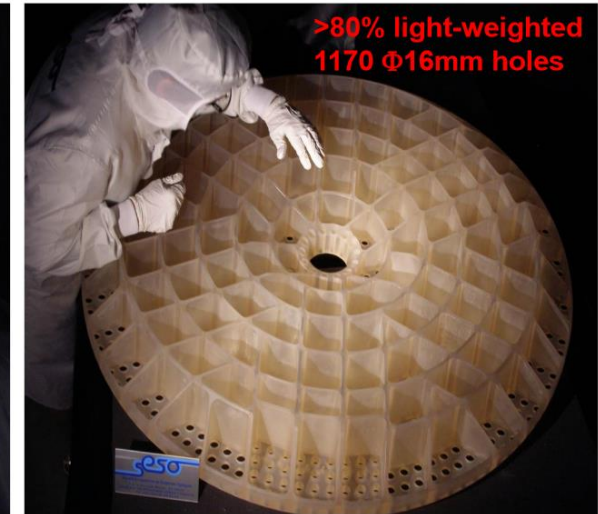
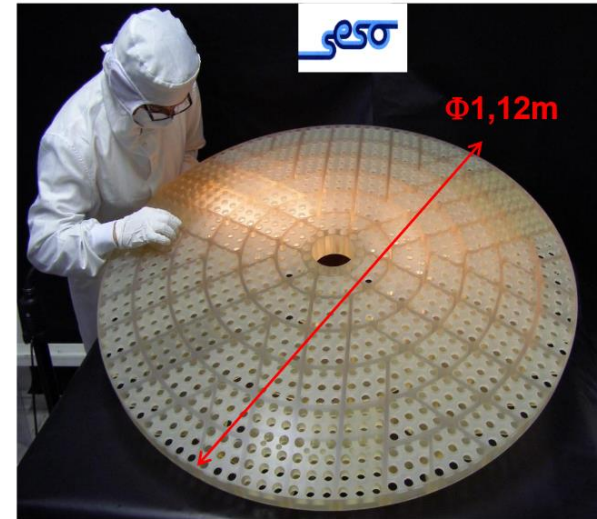


## AND SO MANY MORE..

### Thales SESO

Manufacturing of Zerodur reference back plane for the VLT Deformable Secondary Mirror (OA Facility on UT4)

- 1.12m dia., > 80% light-weighted
- 1170 holes for actuators



### Boostec Mersen

Manufacturing of :

The 6 Silicon Carbide petals for the ELT M5 fast tip-tilt mirror.

SiC reference back plane for the ELT M4 Adaptive mirror



# AND SO MANY MORE..



## SAFRAN REOSC

Polishing of all the ELT telescope optics  
M1 segments, M2, M3, M4 thin shells and M5

See talk of Philippe RIOUFREYT

**FOGALE nanotech (with Micro-Epsilon – D)**  
Manufacturing of ELT segments edge-sensors + electronics  
~ 4500 sensors and 800 reading electronics

See Didier ROSIERE talk





## **TECHNOLOGICAL DEVELOPMENT – A VIRTUOUS CIRCLE**

**ESO has always played a major role for the technological development with industry**

- Via direct solicitation to partners to improve performance,
- Through European programs (EC Framework Programs) for R&D aspects,
- By using Prototype and Demonstrator contracts to mature technologies,
- Often in close collaboration with research center or laboratories.

**The know-how and expertise developed by French industry for/through ESO programs can be exported very well and are often key-elements of other major physics and astrophysics projects around the world.**

**This, in turn, benefits ESO and the astronomical community as a whole...**

## **THE FRENCH INDUSTRY IN THE ESO PROGRAM - CONCLUSION**

- **Historical contribution to the La Silla, Paranal and ALMA observatories construction,**
- **Strong involvement in all generations of instruments (VIMOS, NACO, ... SPHERE, MUSE..),**
- **Close collaboration with laboratories for innovative instrumentation and TRL increase,**
- **For several years, deeply involved in the preparatory and construction phases of the ELT,**
- **On the recent period (2015-2020), ESO contracts represent 145 M€ of direct return to French industry (does not include subcontracts through other countries' companies ),**
- **Many opportunities to come with the ELT instruments Phase C !!  
HARMONI, MICADO, MORFEO, METIS, ANDES, MOSAIC, PCS...  
(Optics, Cryogenics, DMs, Cameras, etc..)**



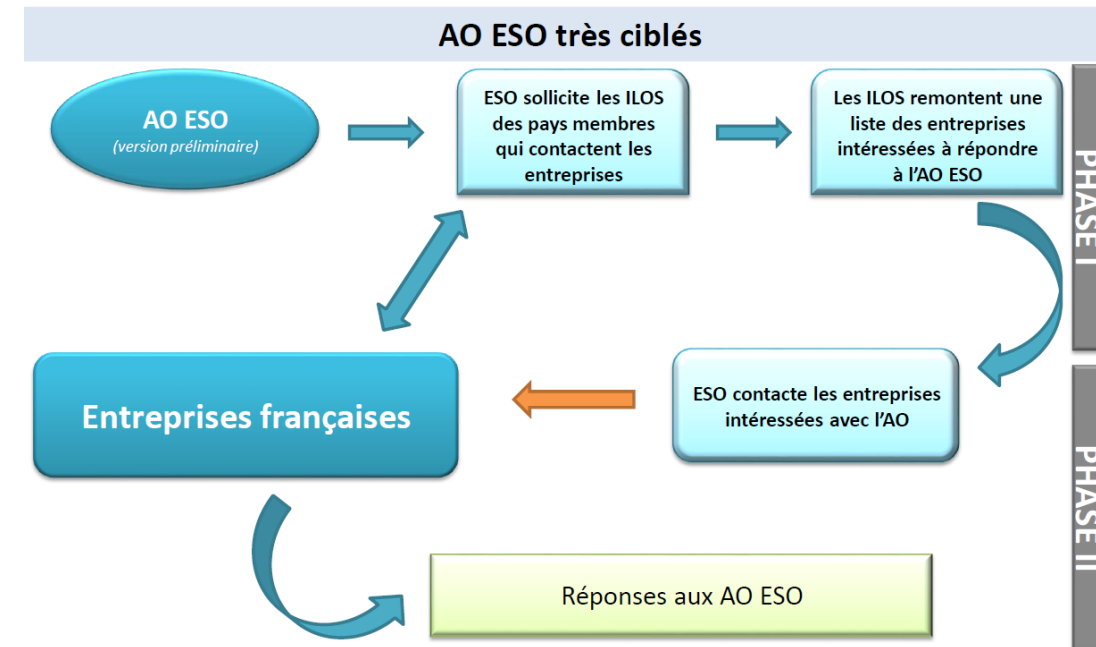
For France, the Industrial Liaison Officer is **Laurent Jammes (CNRS/INSU - DRI)**

## Important role for ESO, the French community and industry

” The role of the Industrial Liaison Officer is to establish contacts between ESO and (potential) suppliers and to support ESO in its search for the different suitable suppliers in their respective country in order to maximize the chance to distribute the ESO contracts as fairly as possible amongst suppliers in the different Member States”

**ILO is a valuable help, during preparation and also when responding to ESO calls for tenders.**

Do not hesitate to contact Laurent : [laurent.jammes@cnrs.fr](mailto:laurent.jammes@cnrs.fr)





# ESO AND FRENCH INDUSTRY

ESO 60-YEARS  
2022, NOVEMBER 3RD

**MIRRORS FOR ESO     P. RIOUFREYT  
(SAFRAN/REOSC)**

**SENSORS FOR ESO     D. ROZIERE  
(FOGALE NANOTECH)**

**OPTICS FOR ESO :     P. GODEFROY  
(BERTIN/WINLIGHT)**

