CTA – A NEW WINDOW ONTO THE VIOLENT UNIVERSE

TOPICS

- Overview
- CTA telescopes
- CTA organization, status and planning
- Future legal structure, governance, organization
- Site selection
- Feasibility and risks

Will not discuss all transparencies in detail, some serve for reference

OVERVIEW

Motivation

The Milky Way in gamma rays

Worldwide unique infrastructure

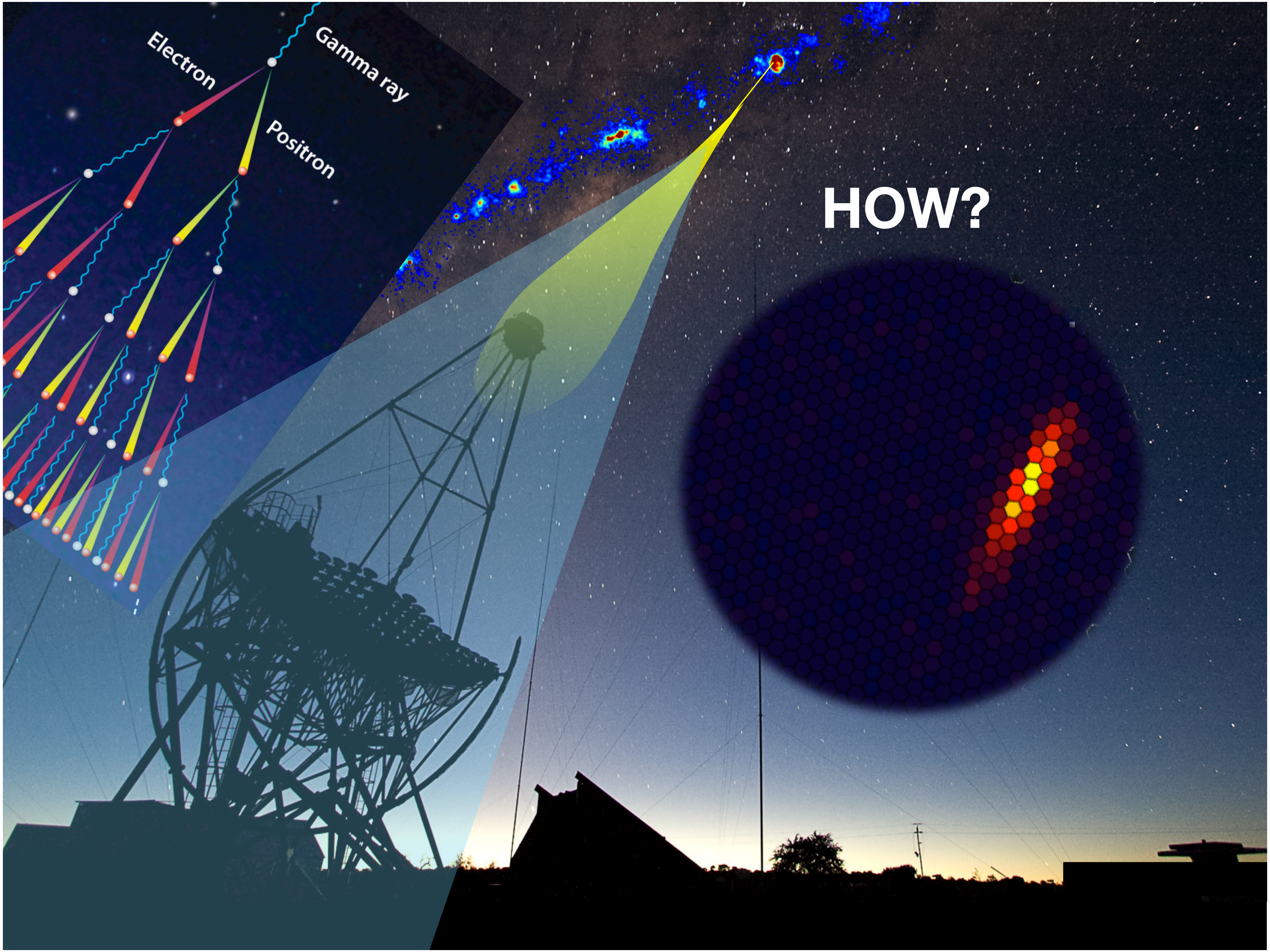
Explores top 4 decades of radiation from space

Factor 10 increase in key performance parameters over existing facilities

Full-sky coverage

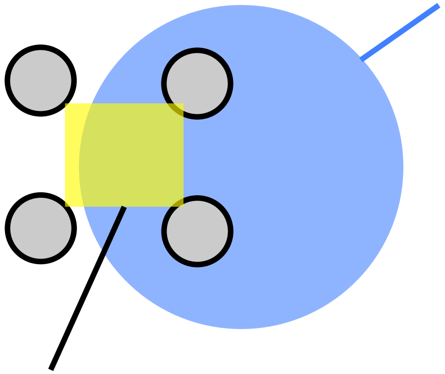
Goals: understanding cosmic particle accelerators and their impact on the Universe; searching for Dark Matter; cosmology; fundamental physics; …

Large community



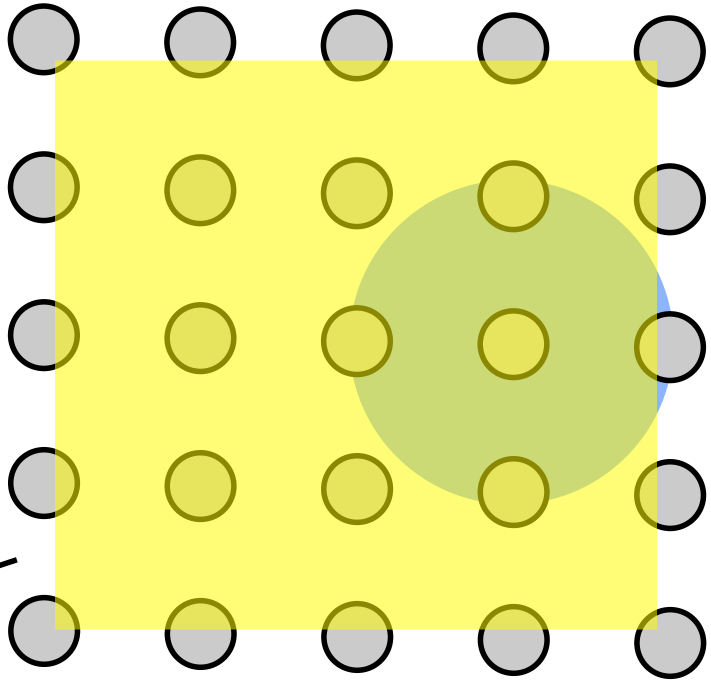
HOW?

FROM CURRENT ARRAYS TO CTA



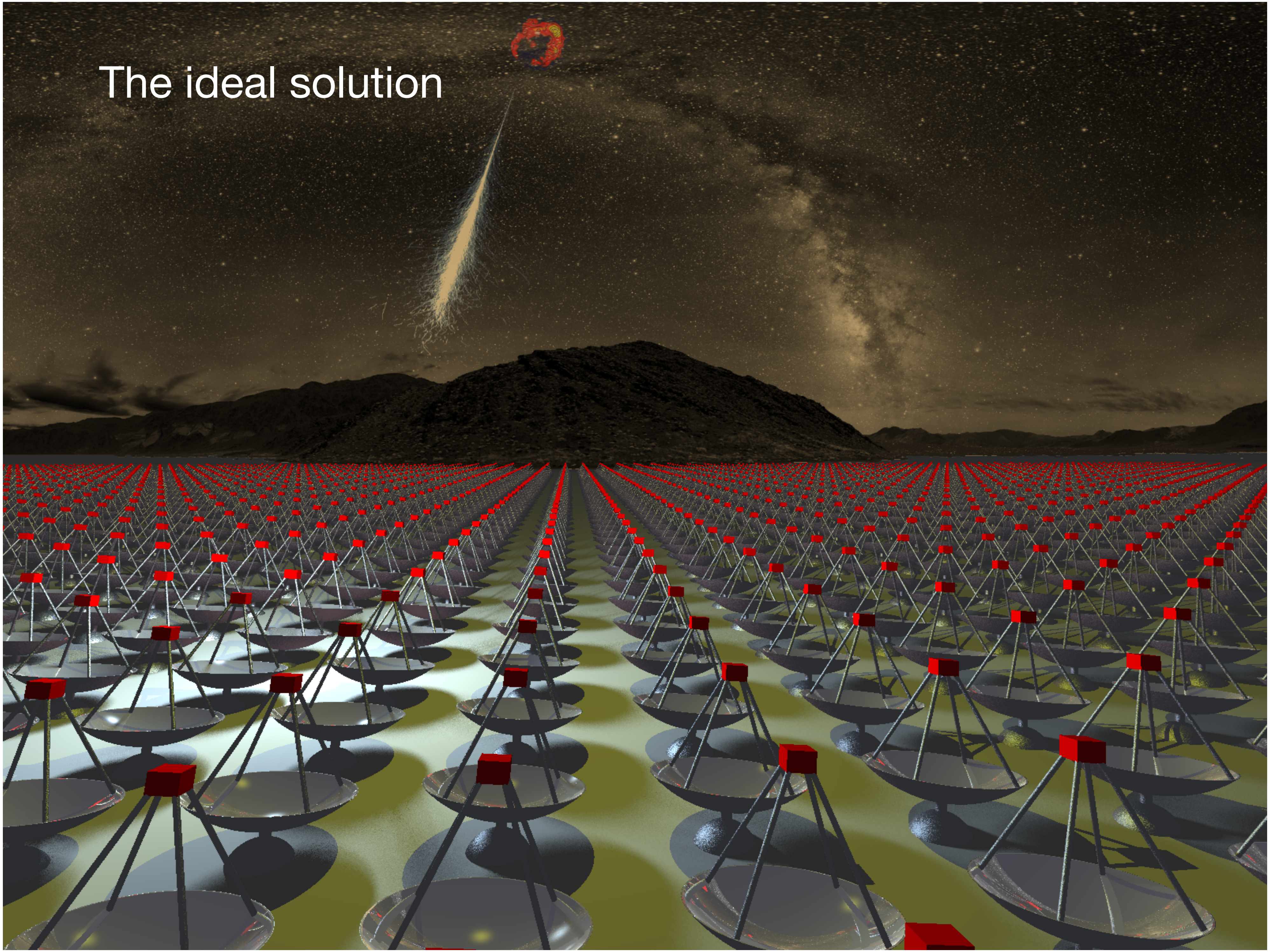
light pool radius
R ≈100-150 m
≈ typical telescope spacing

Sweet spot for
best triggering
and reconstruction:
most showers miss it!



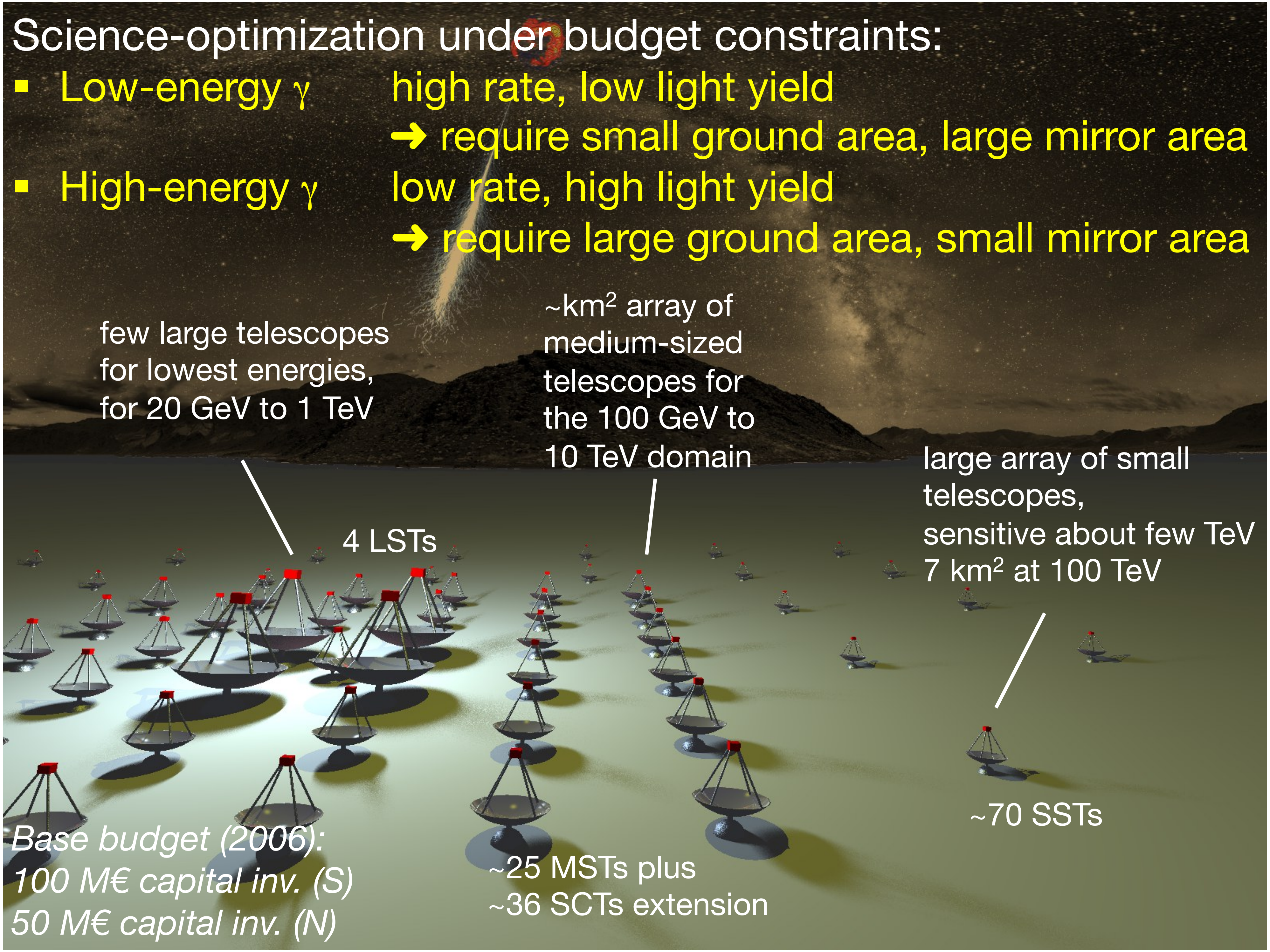
large detection area
more images per shower
lower trigger threshold

The ideal solution



Science-optimization under budget constraints:

- Low-energy γ high rate, low light yield
  ➜ require small ground area, large mirror area
- High-energy γ low rate, high light yield
  ➜ require large ground area, small mirror area



few large telescopes
for lowest energies,
for 20 GeV to 1 TeV

4 LSTs

~km^2 array of
medium-sized
telescopes for
the 100 GeV to
10 TeV domain

~25 MSTs plus
~36 SCTs extension

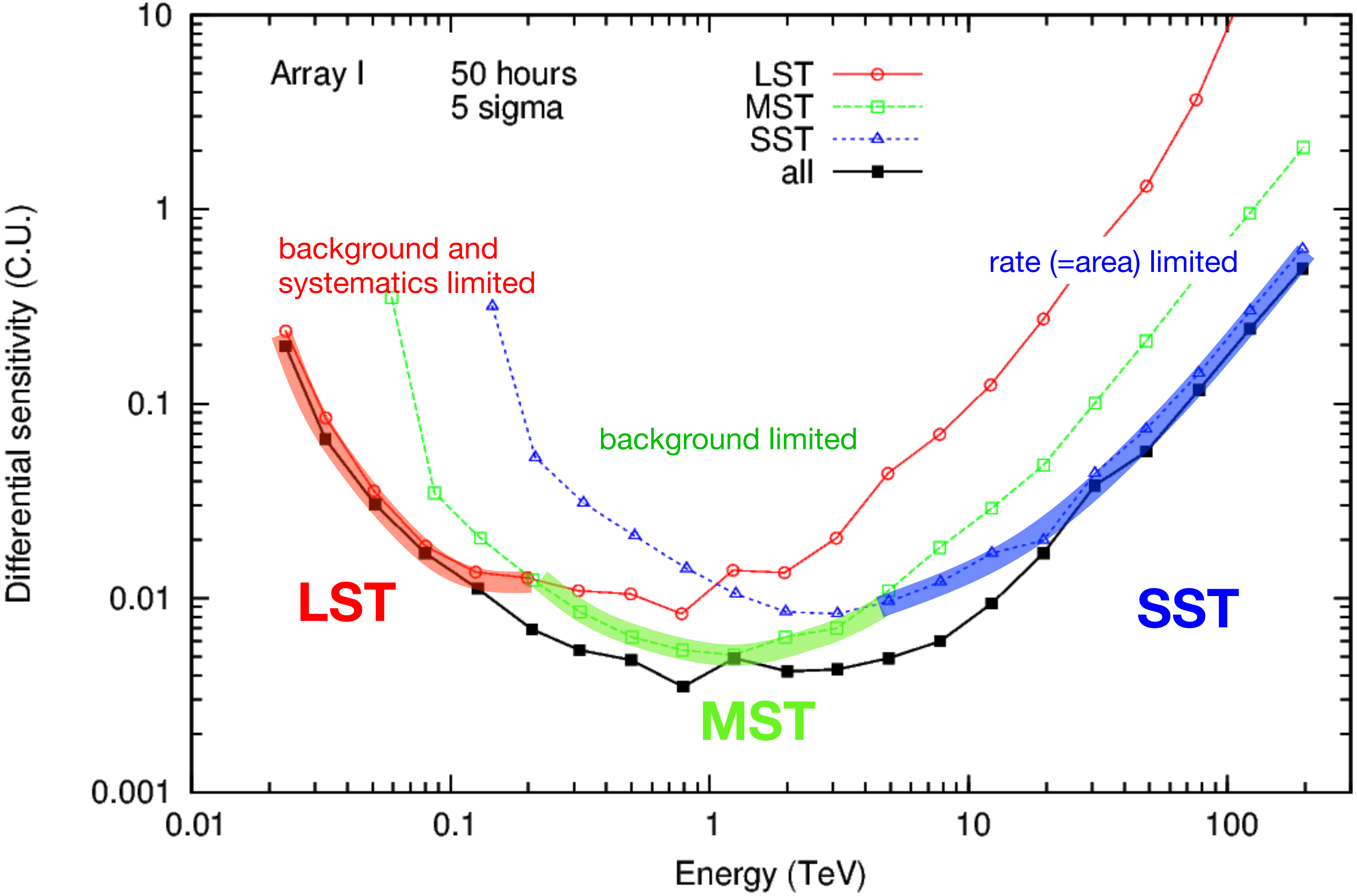
large array of small
telescopes,
sensitive about few TeV
7 km^2 at 100 TeV

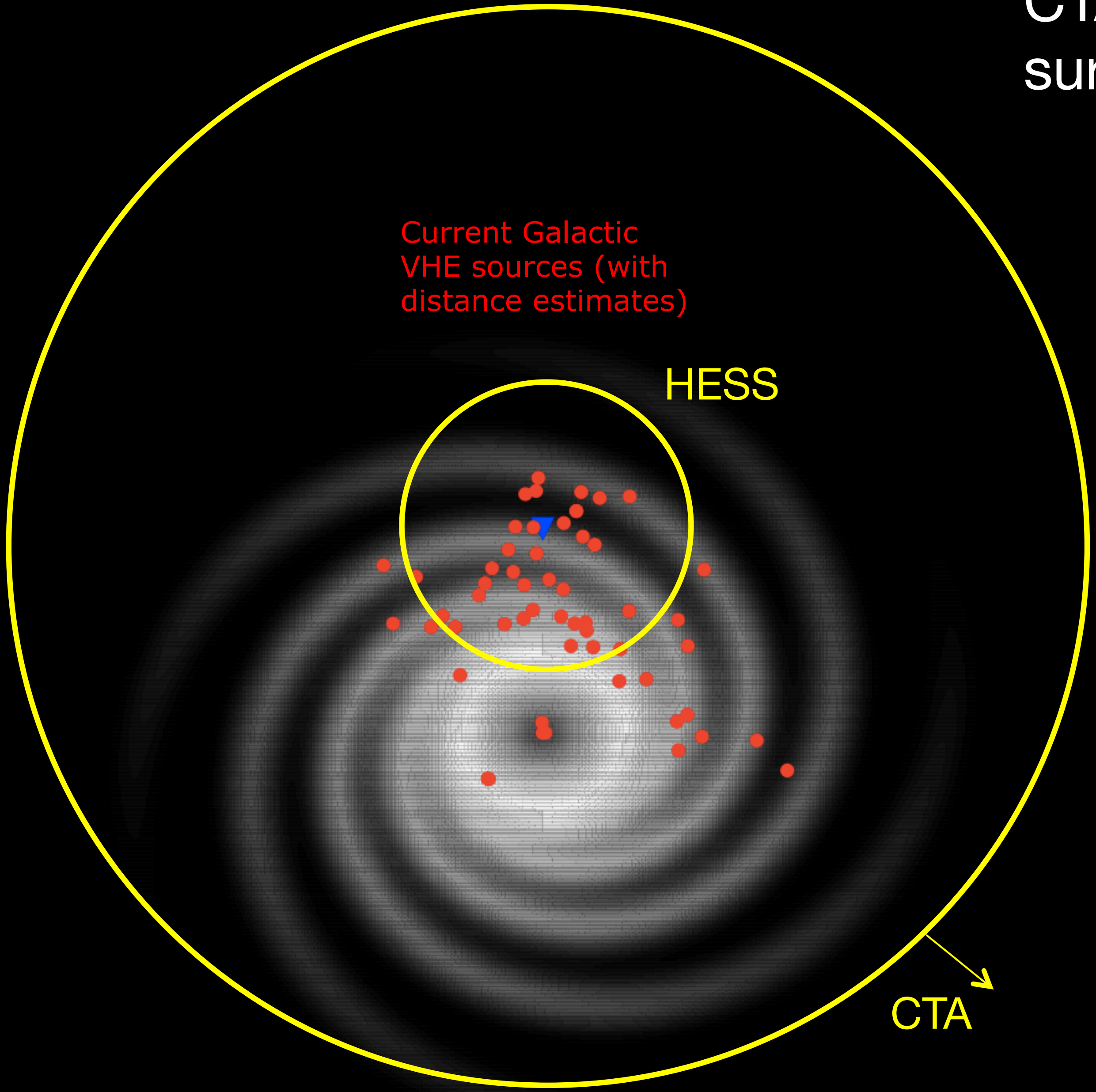
~70 SSTs

Base budget (2006):
100 M€ capital inv. (S)
50 M€ capital inv. (N)

SENSITIVITY (IN UNITS OF CRAB FLUX)

FOR DETECTION IN EACH 0.2-DECADE ENERGY BAND





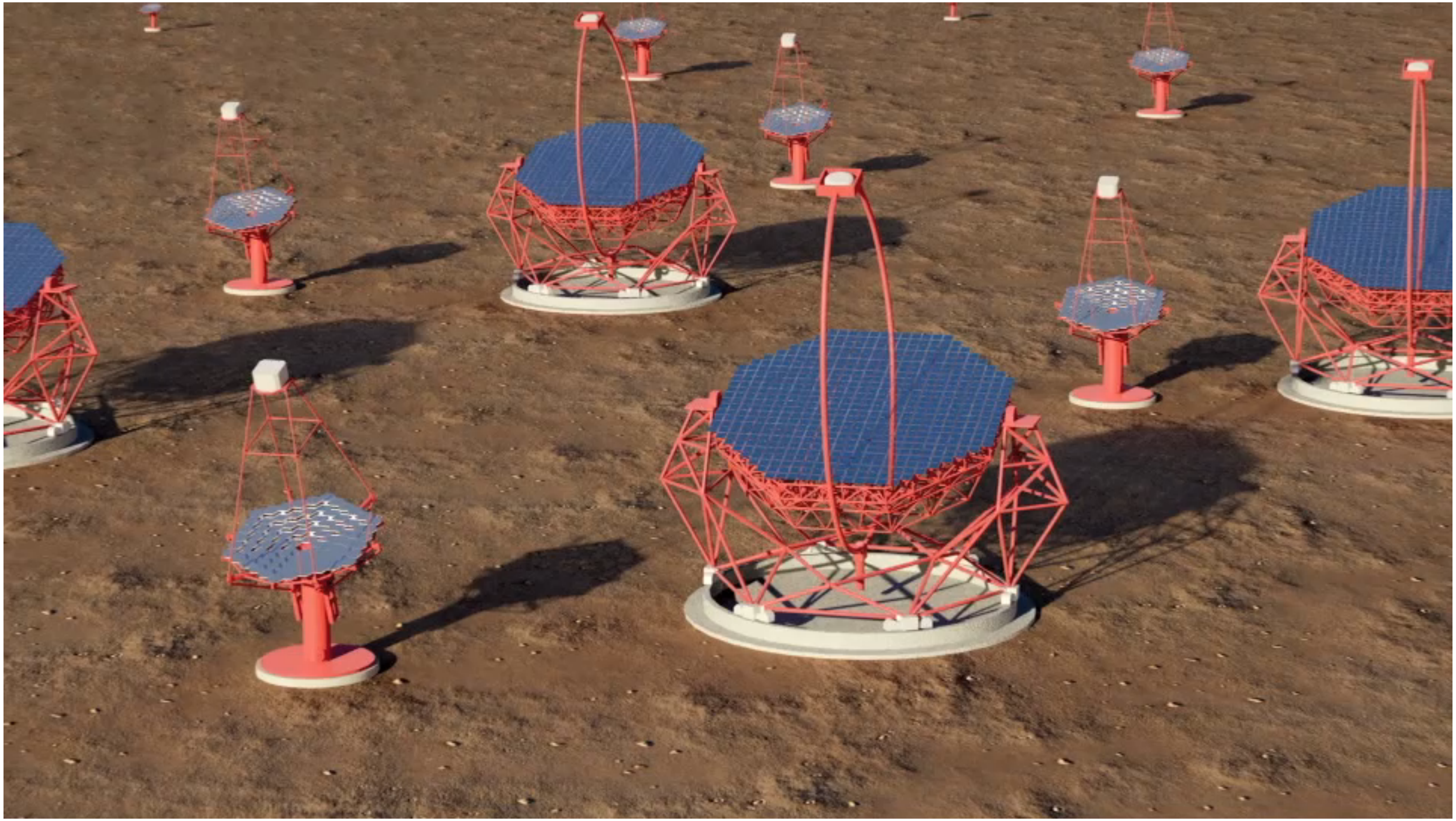
CTA as ultimate survey machine

CTA as ultimate flare machine

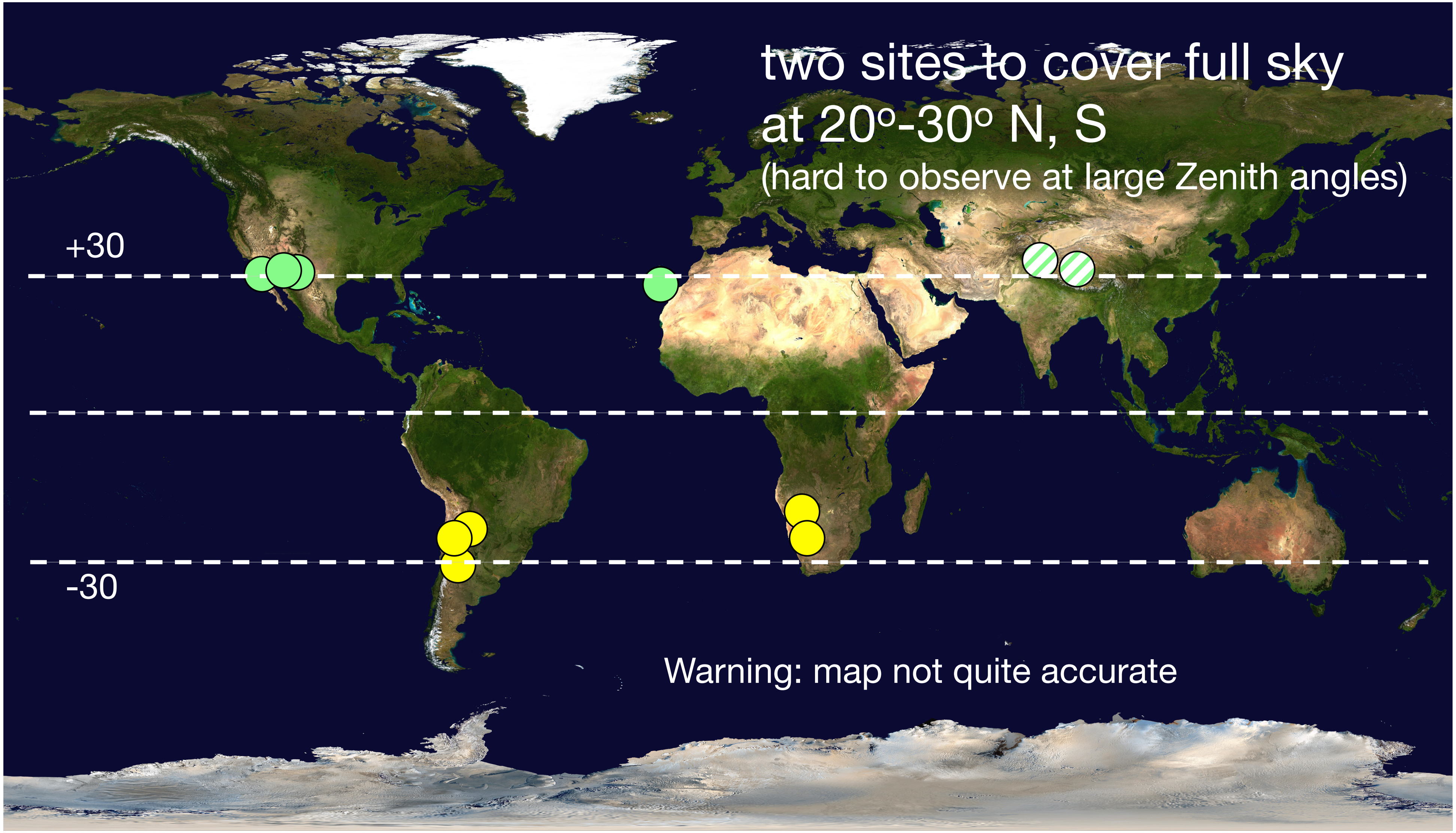
at 25 GeV, for flares 10000 times more sensitive than Fermi

Coherent full-sky coverage from two sites

Credit:
Multimedia Service,
Institute of Astrophysics of Canary Islands



SITE CANDIDATES

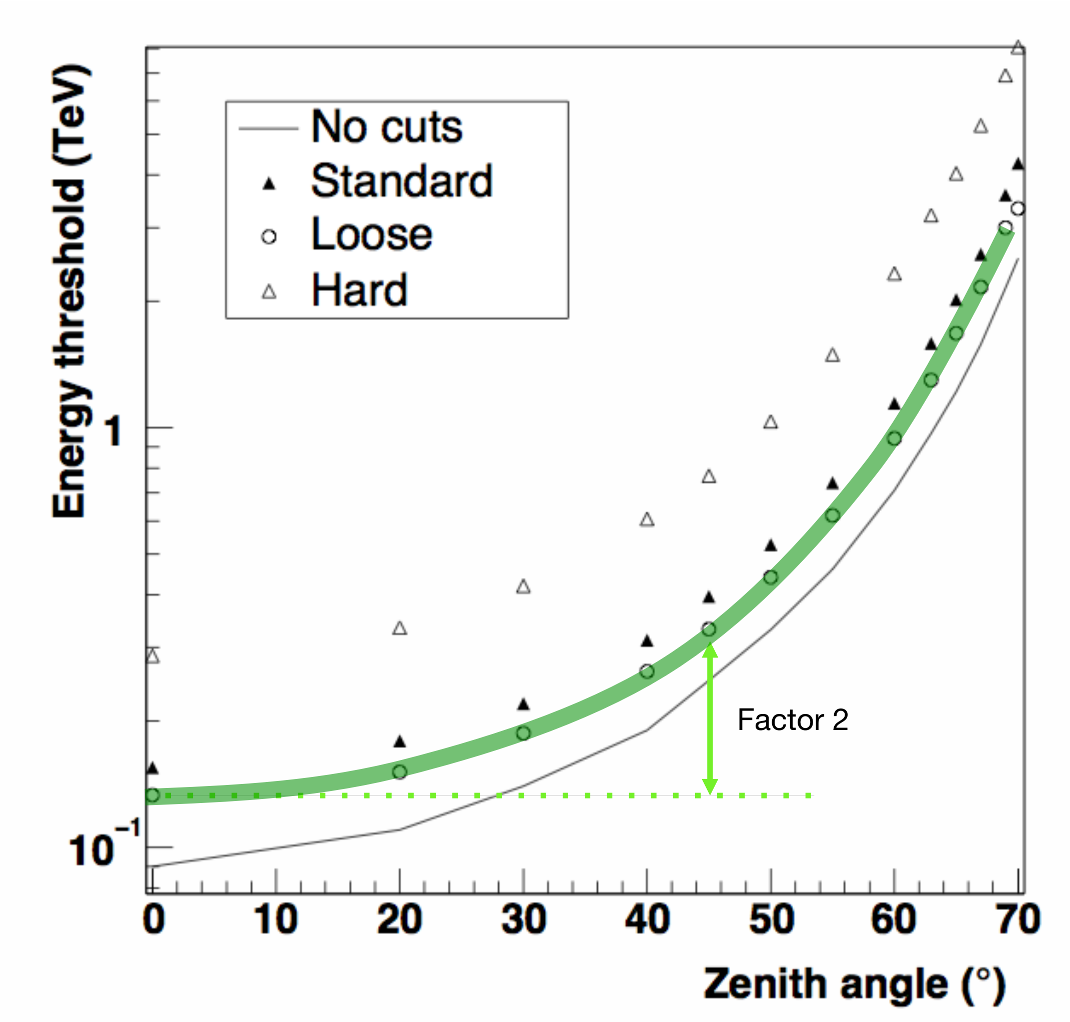

two sites to cover full sky at 20º-30º N, S

(hard to observe at large Zenith angles)

Warning: map not quite accurate

LATITUDE & SKY COVERAGE

Energy threshold is strong function of zenith angle



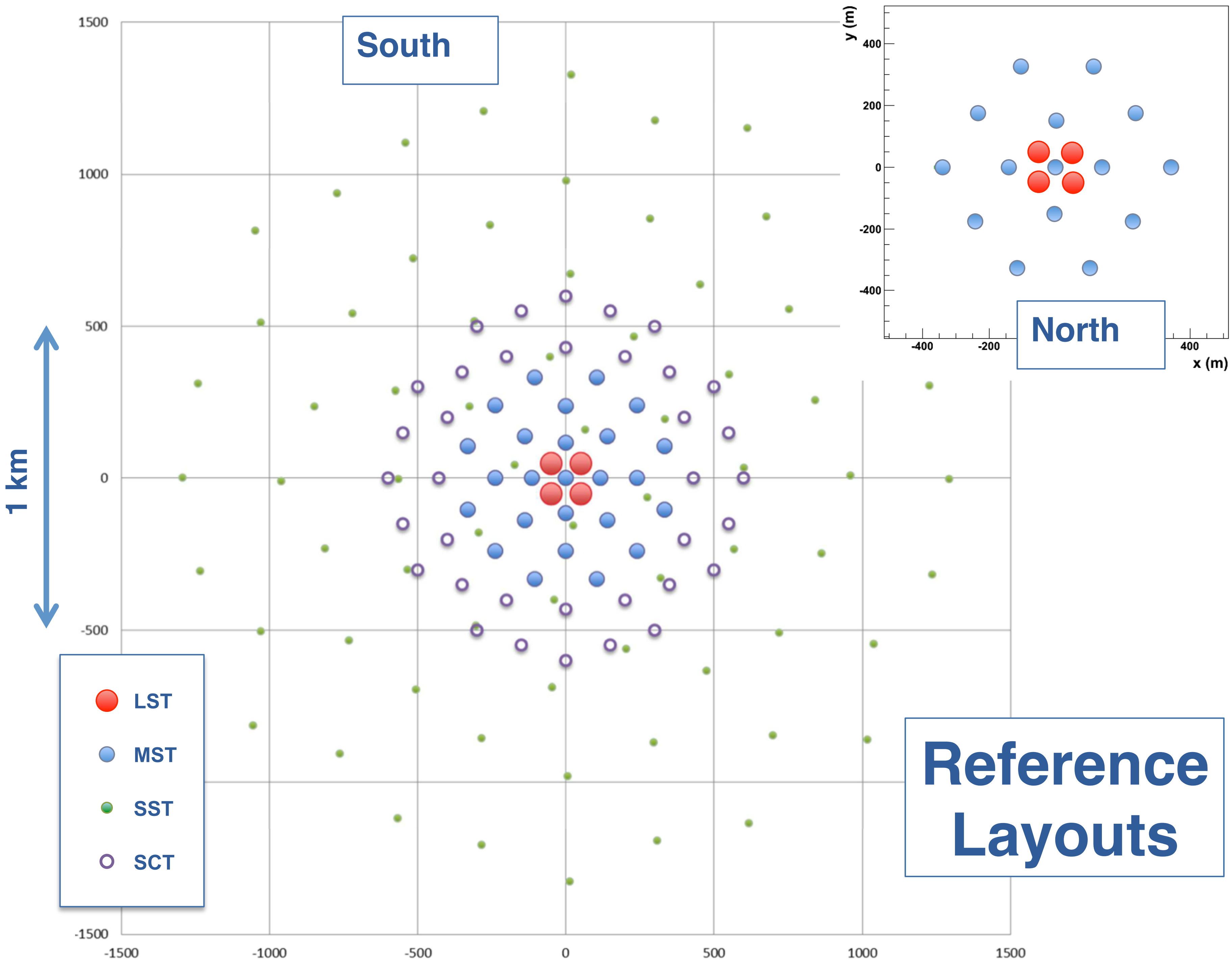
ideal: <30° zenith angle
ok: <45° zenith angle

Sites at ±45°:
full sky coverage

Sites at ±30°:
optimal coverage of 87% of sky

… higher order corrections if sites not identical…
… best single observatory at equator …
… Galactic Center Dec -29° …

Reference Layouts



SITE ENVIRONMENTAL CONDITIONS

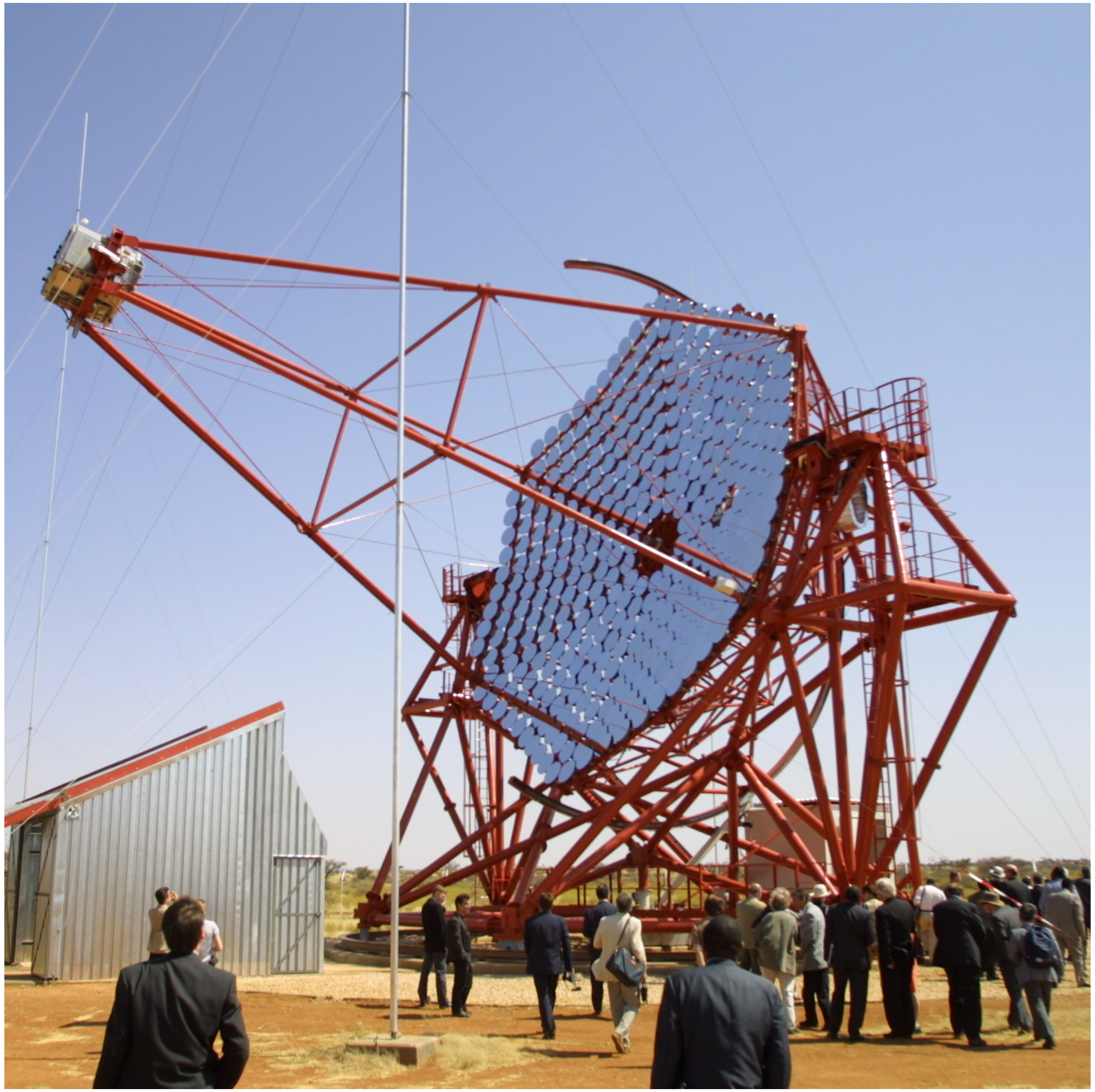
Cannot afford domes

Constraining:

- peak wind speed
- snow loads
- sand storms
- hail

Not so disturbing:

- temperatures & gradients



WHAT WE DON'T CARE ABOUT

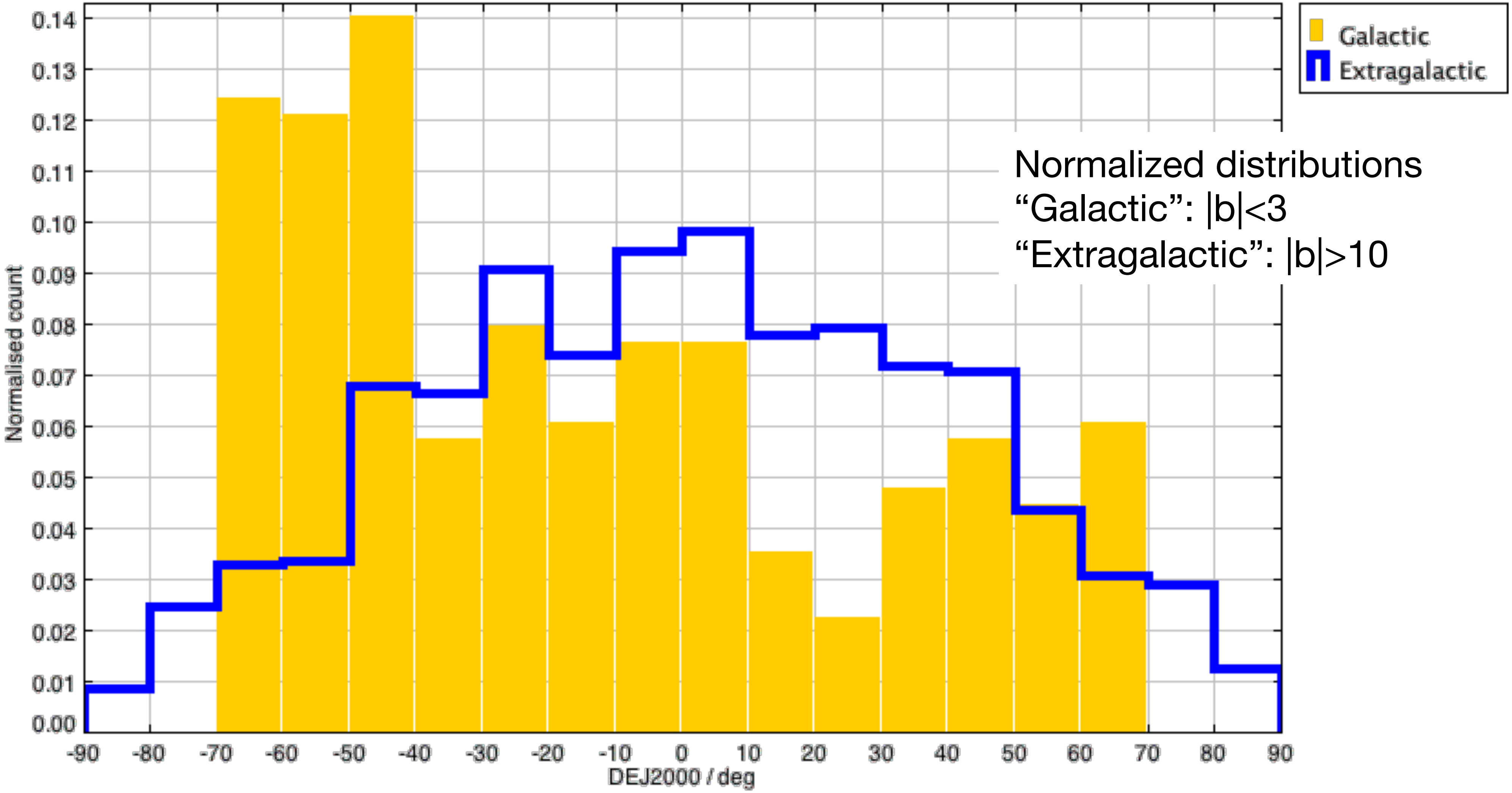
Seeing: Pixel size of CT's is 0.1° – 0.2°
Don't care about seeing

Water vapor: no significant scattering or absorption of Cherenkov light
Don't care as long as it is vapor

Tracking, shaking: no need to point / track very precisely as long as one knows where the telescope points during the 10 ns exposure

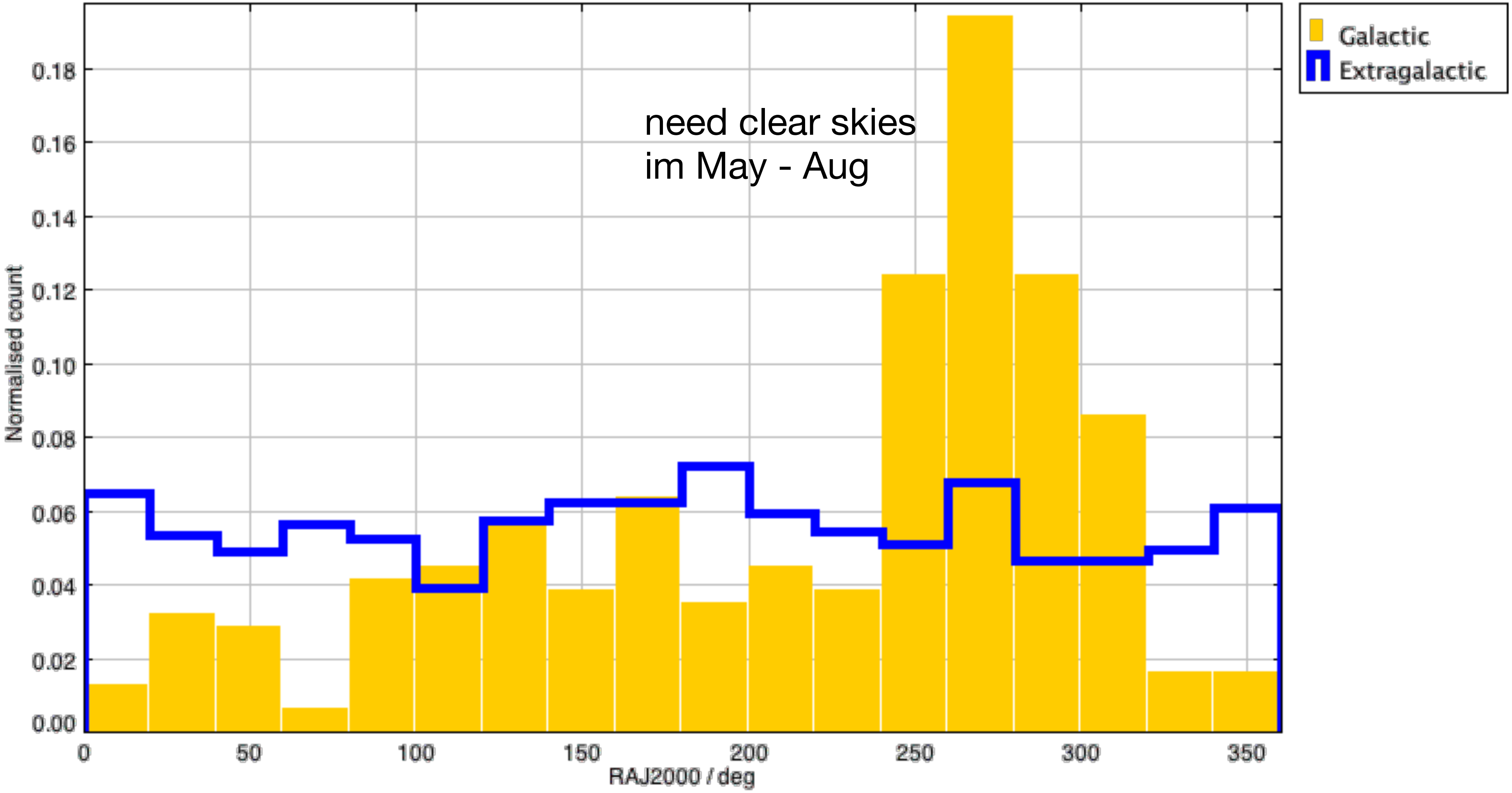
➜ Site requirements: John Carr

SKY & SEASONAL COVERAGE:
FERMI-LAT SOURCE CATALOG



Normalized distributions
“Galactic”: |b|<3
“Extragalactic”: |b|>10

SKY & SEASONAL COVERAGE: FERMI-LAT SOURCE CATALOG



need clear skies
im May - Aug

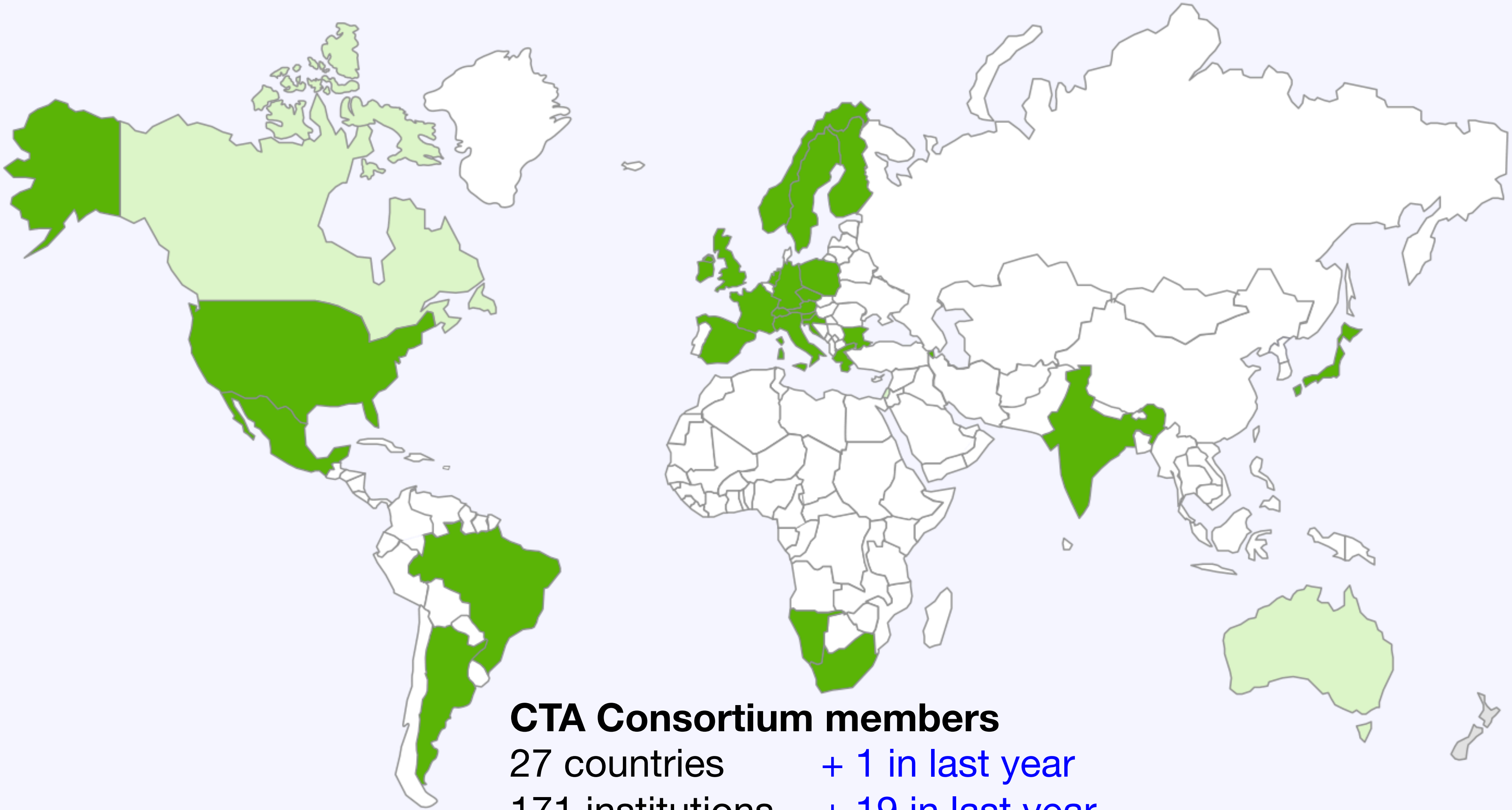
Sept Dec Mar Jun Sept

COMMUNITY

CURRENTLY ENGAGED IN CTA

(subset of future user community)

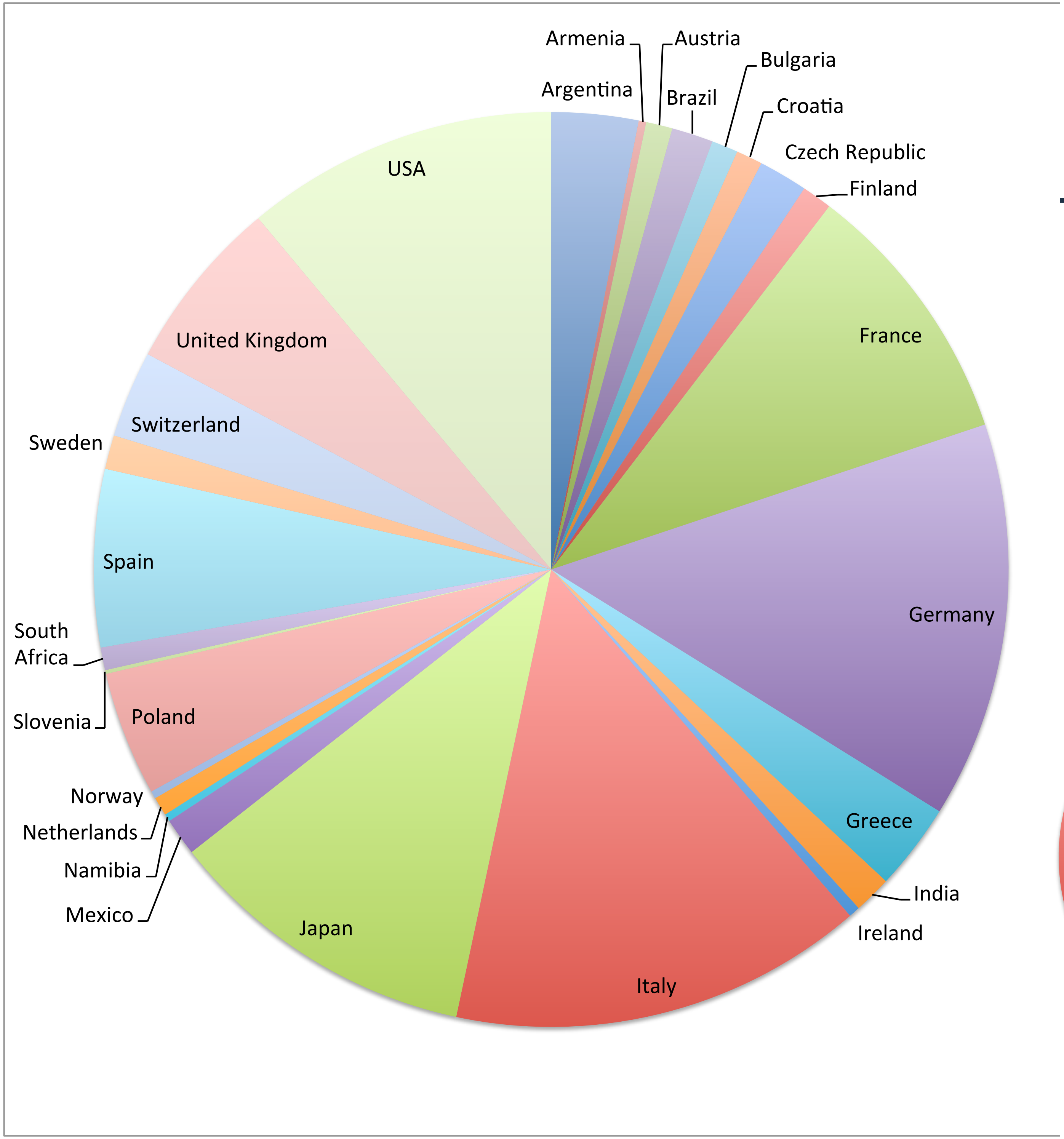
🟩 Members (27 countries)
▢ interested to join
Canada, Australia, Israel

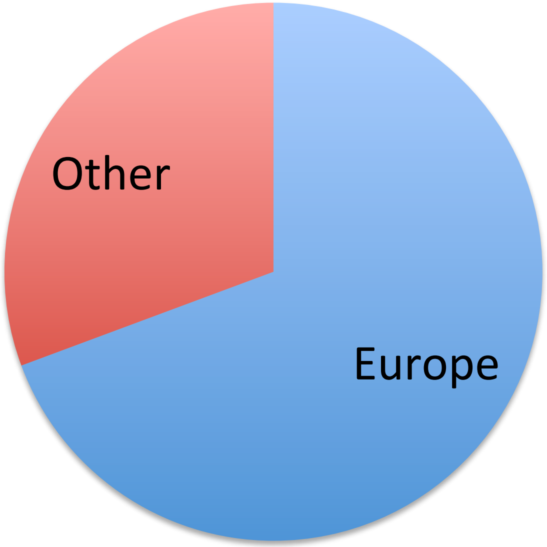


CTA Consortium members

27 countries	+ 1 in last year
171 institutions	+ 19 in last year
1058 persons	+ 198 in last year

CTA scientists

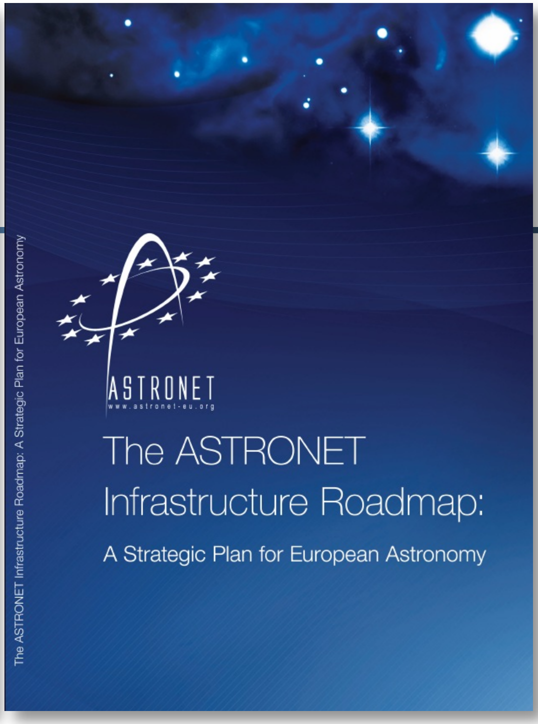


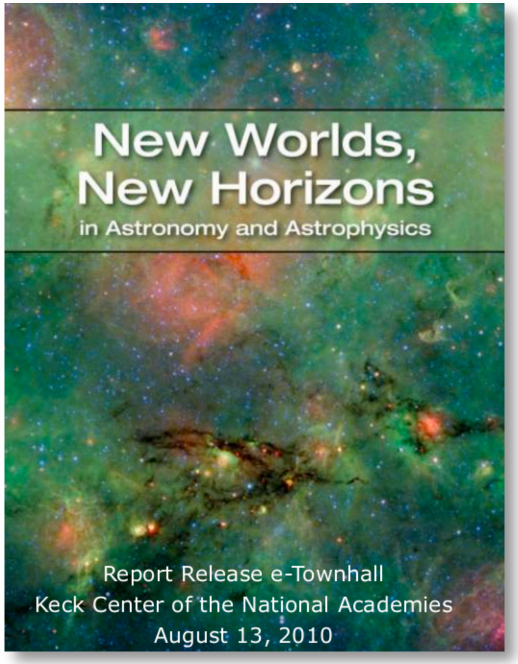


cta
cherenkov telescope array

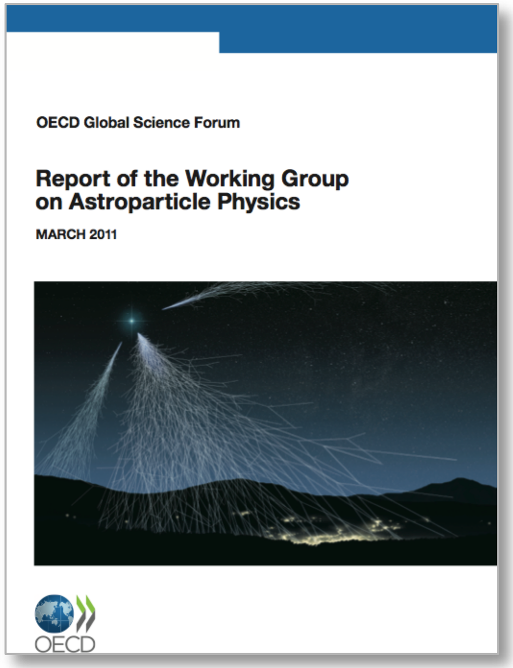
RECOMMENDED BY NATIONAL AND INTERNATIONAL ROADMAPS …


ASTROPARTICLE PHYSICS
the European strategy
ASPERA
http://www.aspera-eu.org

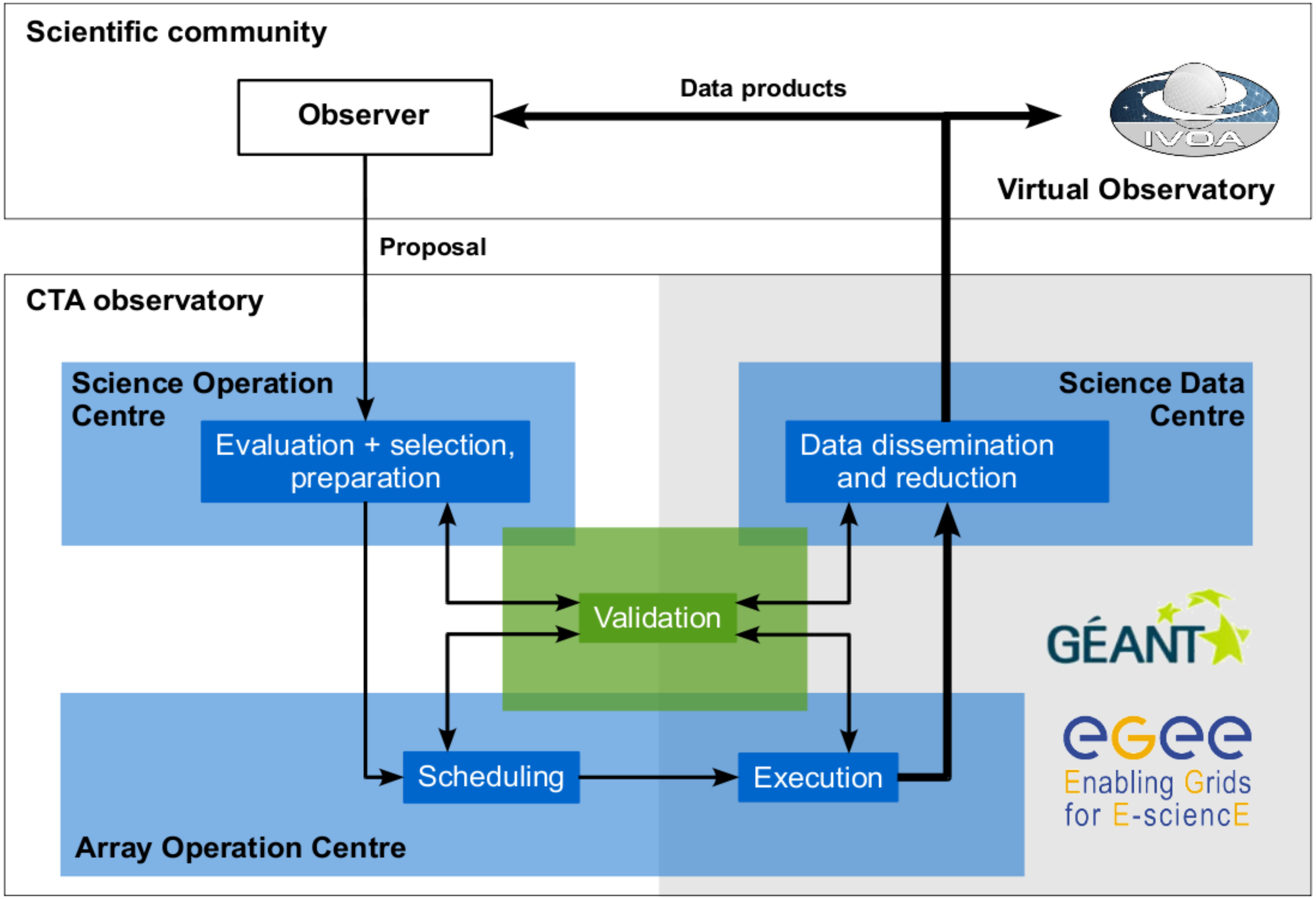

The ASTRONET Infrastructure Roadmap: A Strategic Plan for European Astronomy
ASTRONET
www.astronet-eu.org
The ASTRONET Infrastructure Roadmap:
A Strategic Plan for European Astronomy


New Worlds, New Horizons
in Astronomy and Astrophysics
Report Release e-Townhall
Keck Center of the National Academies
August 13, 2010


European Strategy Forum on Research Infrastructures
ESFRI
EUROPEAN ROADMAP FOR RESEARCH INFRASTRUCTURES
Roadmap 2008
E 2008


OECD Global Science Forum
Report of the Working Group on Astroparticle Physics
MARCH 2011
OECD

FOR THE FIRST TIME IN THIS FIELD: OPEN ACCESS



ACCESS AND DATA POLICY

Peer review and selection of proposals (expect that demand exceeds available time by large factor)

Detailed policies to be defined by funding agencies

Currently envisioned

- Large Key Science Programs (surveys) use 1/3 to 1/2 of time
- Bulk of time open for proposals from participating countries
- Access possibility for scientists worldwide
- No access fees for individual proposals
- All data will become available on the CTA Archive after a proprietary period
- Fully open access for CTA Archive

CTA TELESCOPES

TELESCOPES

	SST **“small”**	**MST** **“medium”**	**LST** **“large”**	**SCT** **“medium 2-M”**
Number	70 (S)	25 (S) 15 (N)	4 (S) 4 (N)	36 (S)
Spec’d range	> few TeV	200 GeV to 10 TeV	20 GeV to 1 TeV	200 GeV to 10 TeV
Eff. mirror area	$> 5\ \mathrm{m}^2$	$> 88\ \mathrm{m}^2$	$> 330\ \mathrm{m}^2$	$> 40\ \mathrm{m}^2$
Field of view	$> 8^{\circ}$	$> 7^{\circ}$	$> 4.4^{\circ}$	$> 7^{\circ}$
Pixel size ~PSF θ_{80}	$< 0.25^{\circ}$	$< 0.18^{\circ}$	$< 0.11^{\circ}$	$< 0.075^{\circ}$
Positioning time	90 s, 60 s goal	90 s, 60 s goal	50 s, 20 s goal	90 s, 60 s goal
Availability	> 97% @ 3 h/week	>97% @ 6 h/week	>95% @ 9 h/week	>97% @ 6 h/week
Target capital cost	420 k€	1.6 M€	7.4 M€	2.0 M€

LARGE 23 M TELESCOPE

OPTIMIZED FOR THE RANGE BELOW 200 GEV

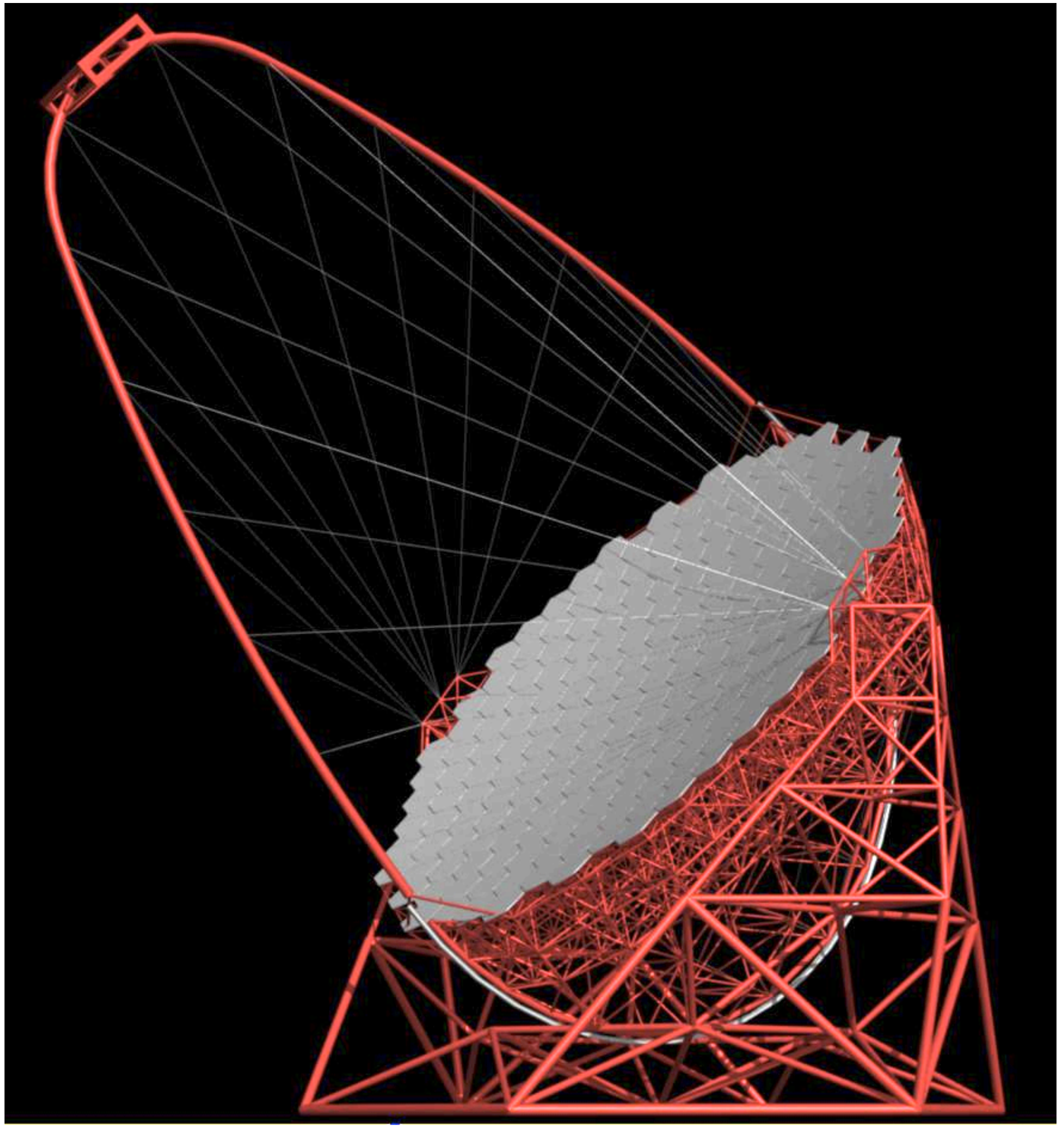
400 m^2 dish area
27.8 m focal length
1.5 m mirror facets

4.5° field of view
0.1° pixels
Camera ∅ over 2 m

Carbon-fibre structure

Active mirror control

4 LSTs on each site



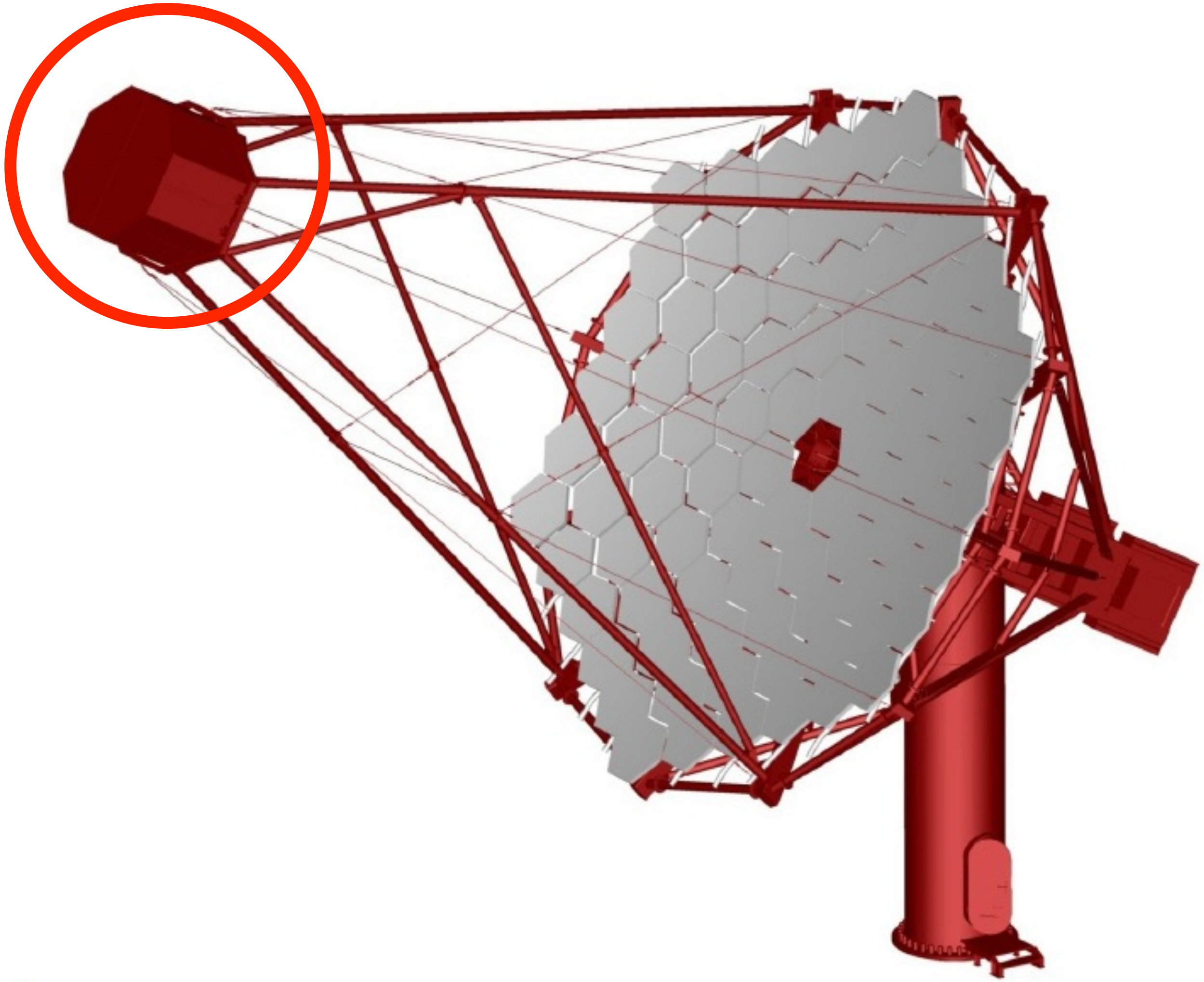
MEDIUM-SIZED 12 M TELESCOPE

OPTIMIZED FOR THE 100 GEV TO ~10 TEV RANGE

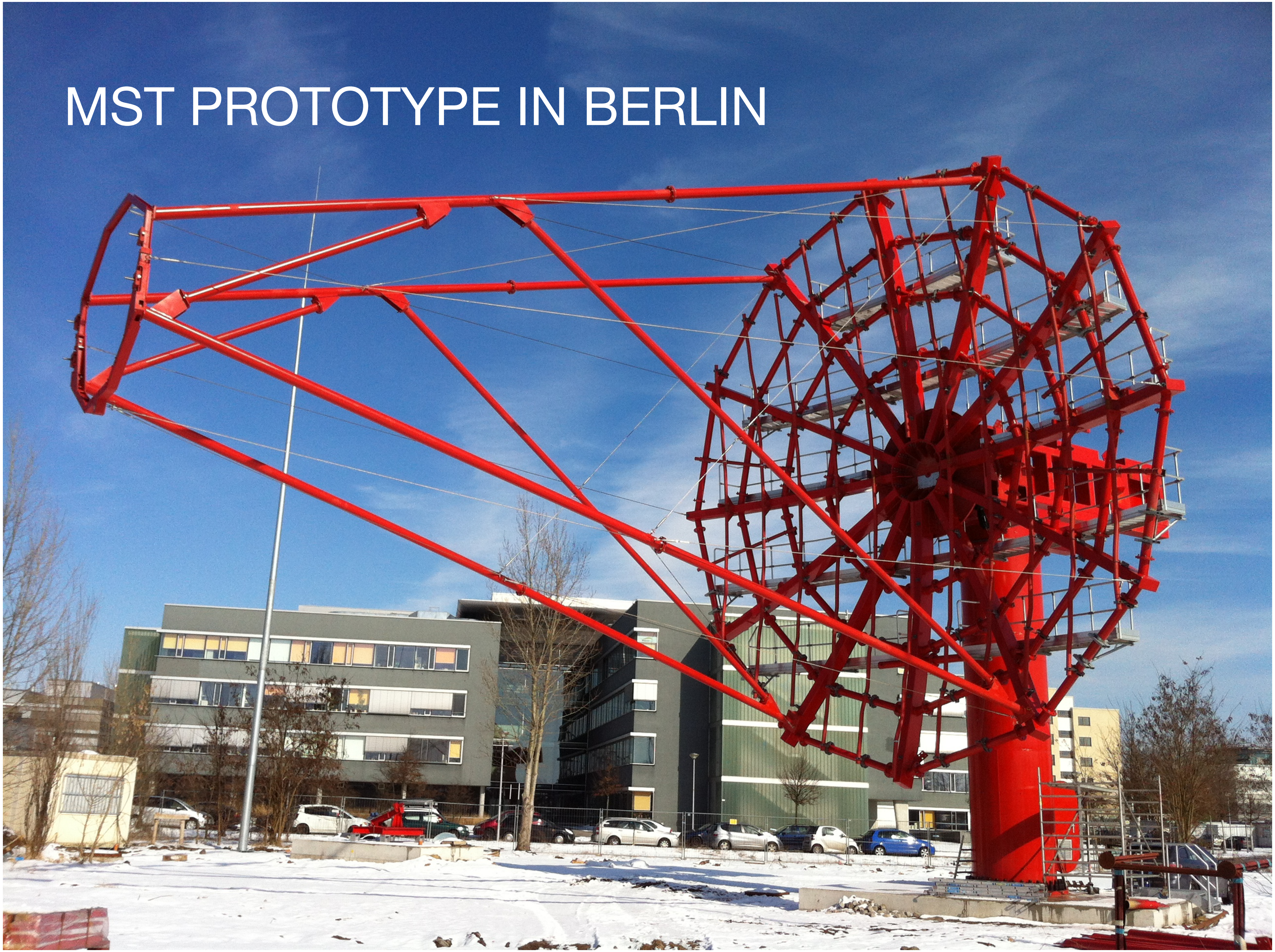
100 m^2 dish area
16 m focal length
1.2 m mirror facets

7-8° field of view
~2000 x 0.18° pixels

25 MSTs on South site
15 MSTs on North site



MST PROTOTYPE IN BERLIN

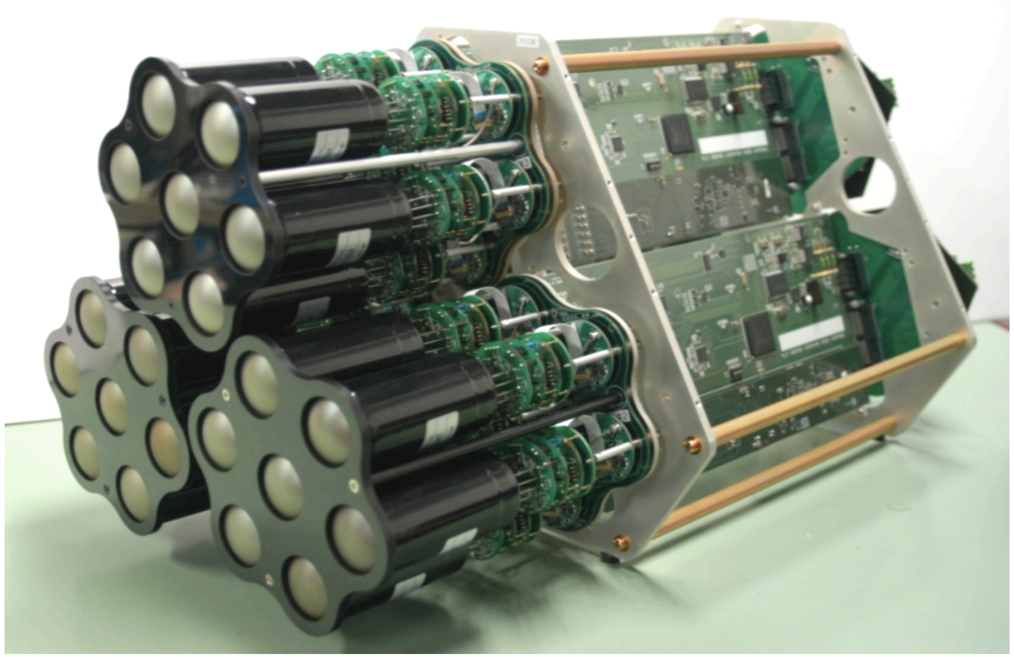


PHOTOMULTIPLIER CAMERAS

Recording signal waveform for “interesting” (triggered) images

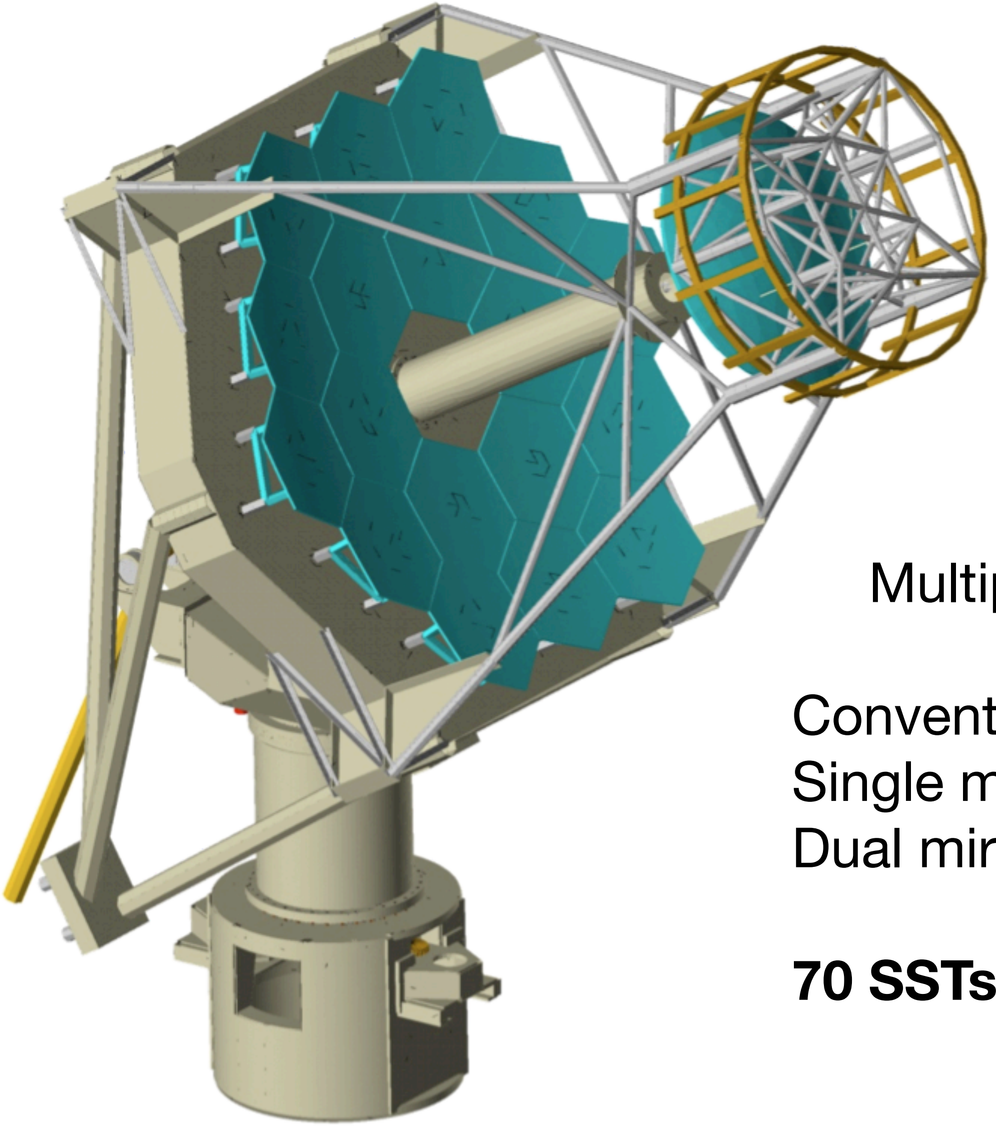
Options:

- Capacitor pipeline + analog trigger + (identical) “drawers”
  - NectarCam
  - DragonCam
- Flash-ADC + digital trigger + rack-based electronics
  - Flashcam



SMALL TELESCOPE

OPTIMIZED FOR THE RANGE ABOVE 10 TEV



ASTRI Design
4.3 m mirror
9.6^o foV
0.25^o pixels

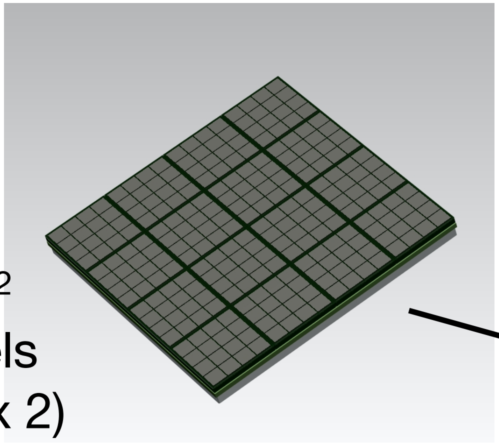
Multiple options under study:

Conventional single mirror, PMT camera
Single mirror, silicon sensor camera
Dual mirror optics, silicon & MAPMT camera

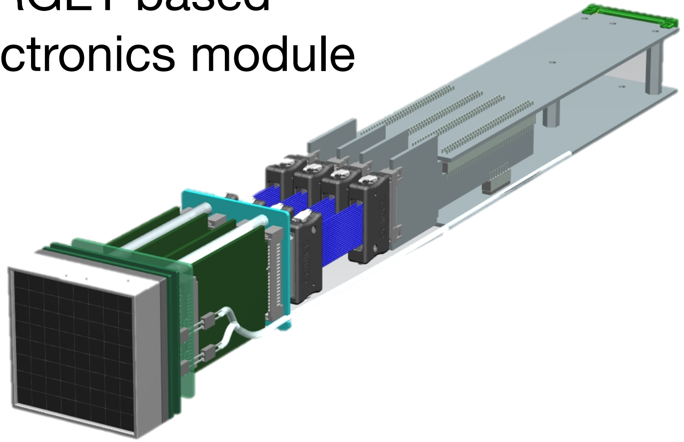
70 SSTs on Southern site

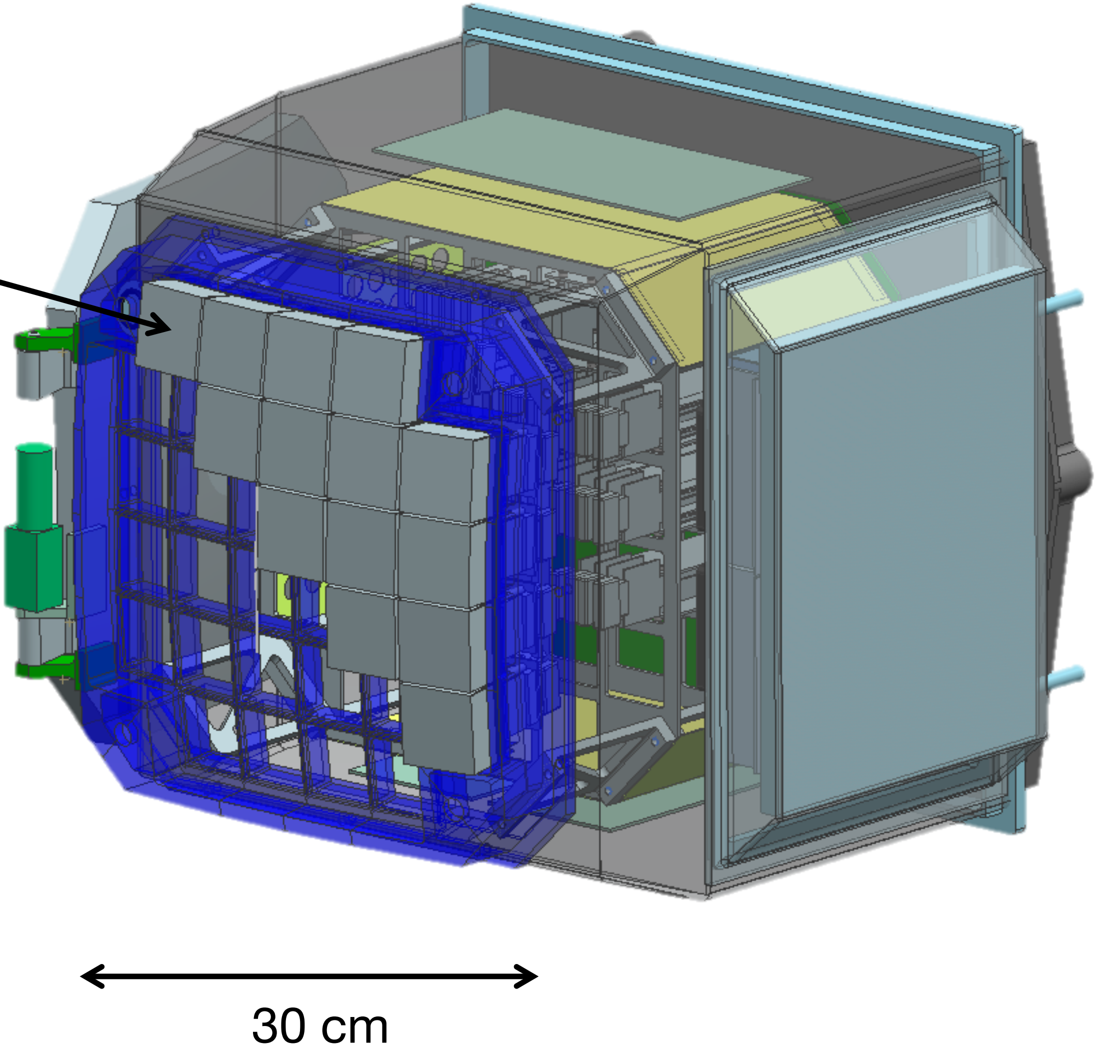
COMPACT SILICON CAMERAS

Hamamatsu
SiPM
50 x 50 mm^2
16 x 16 pixels
(grouped 2 x 2)



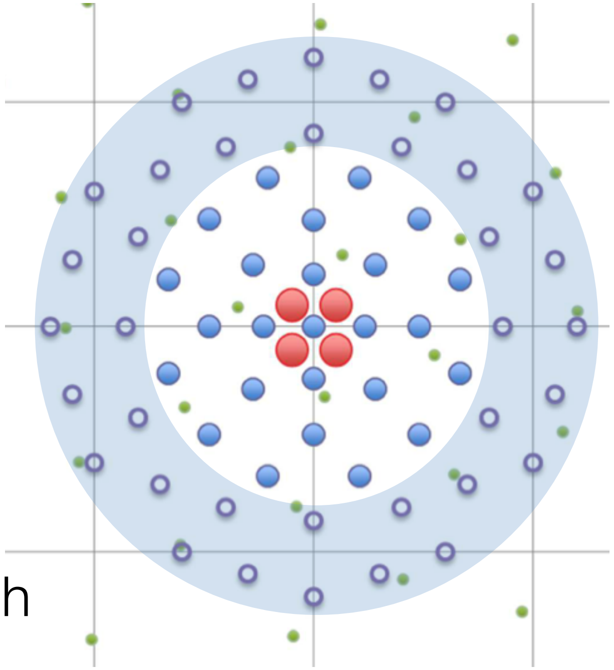
64 Channel
TARGET-based
electronics module





MEDIUM-SIZED DUAL MIRROR TEL.

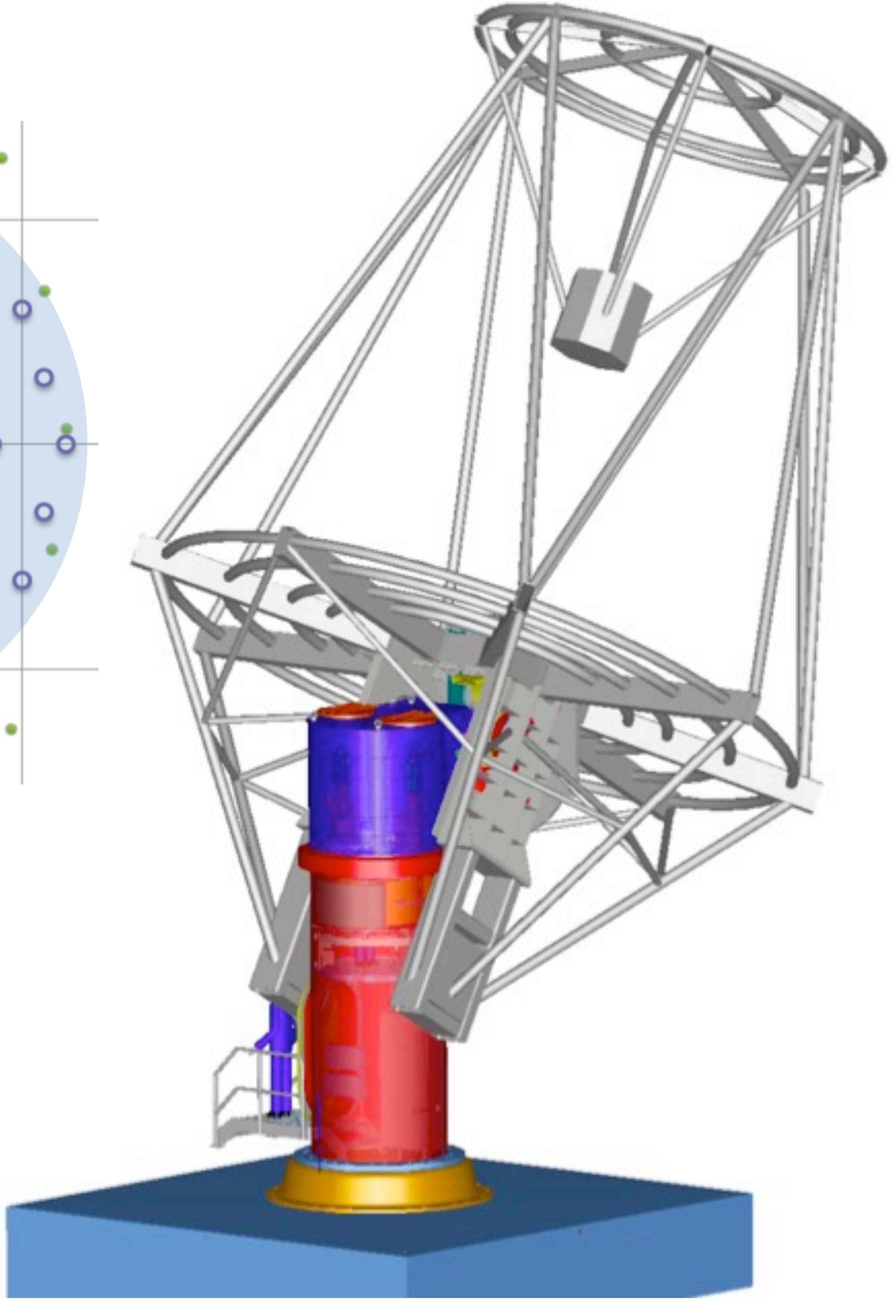
EXTENDING THE MST ARRAY



9.7 m diameter
50 m^2 dish area
5.6 m focal length

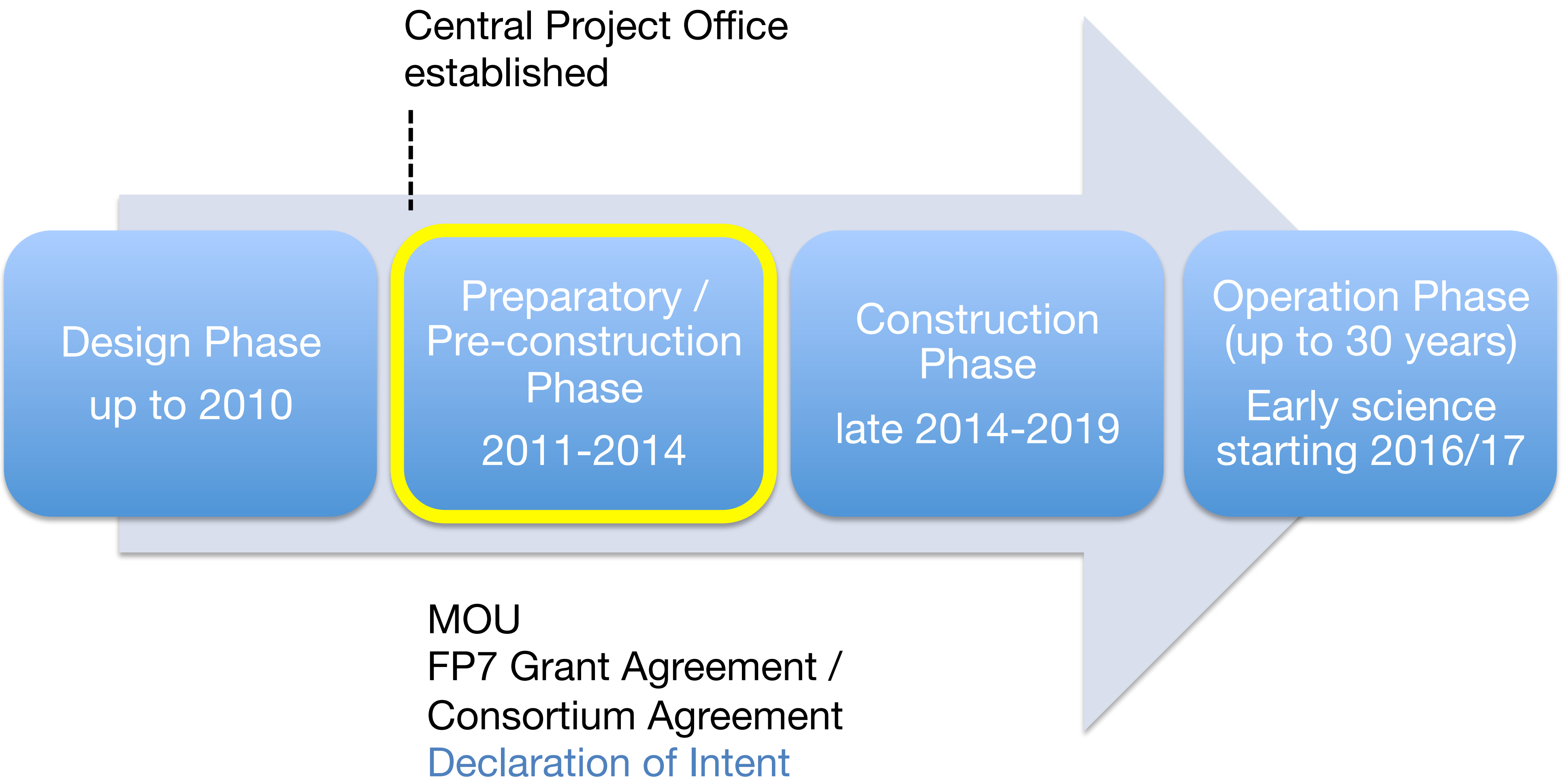
8-9° field of view
11000 x 0.07° pixels

Extend South array
by adding 36 SCTs
contributed mostly by US



CTA ORGANIZATION, STATUS AND PLANNING

CTA TIMELINE



Central Project Office established

Design Phase
up to 2010

Preparatory / Pre-construction Phase
2011-2014

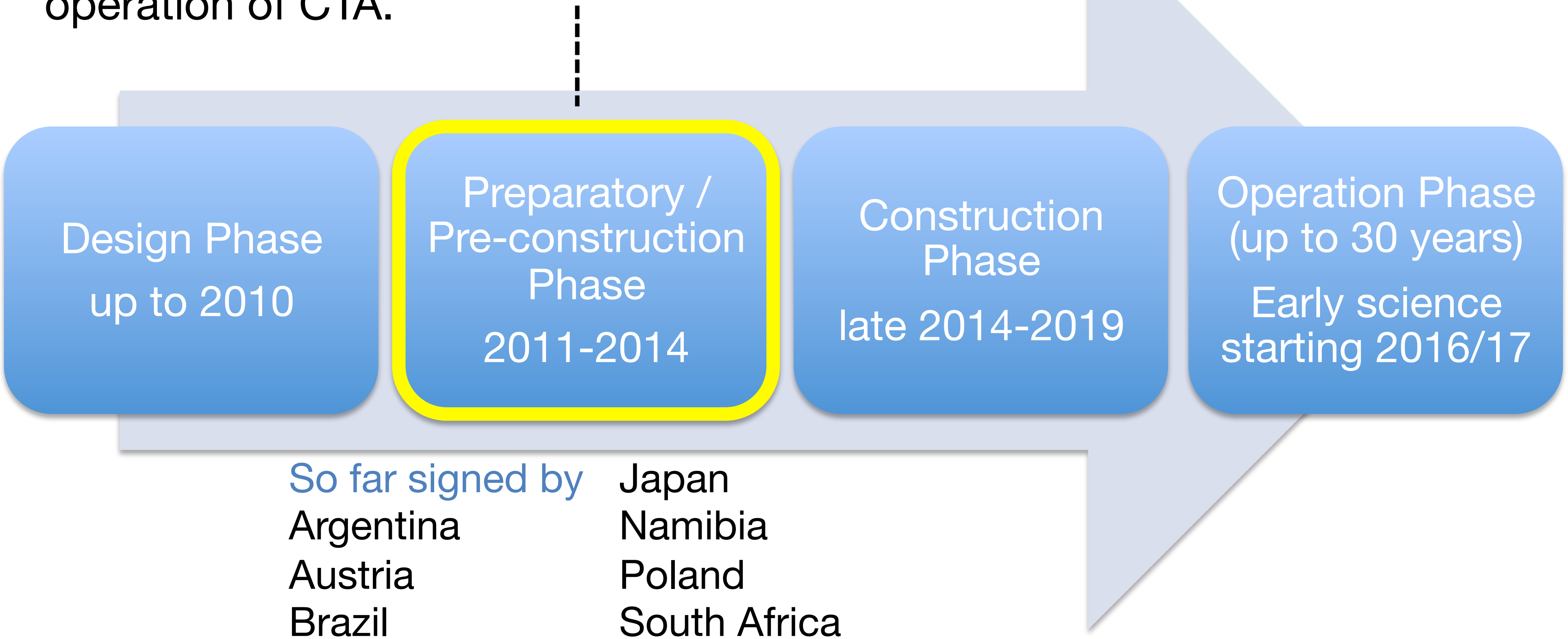
Construction Phase
late 2014-2019

Operation Phase (up to 30 years)
Early science starting 2016/17

MOU
FP7 Grant Agreement /
Consortium Agreement
Declaration of Intent

CTA TIMELINE

"By signing this Declaration of Intent, the signatories – Ministries and Funding Agencies – wish to express their common interest in participating in the construction and operation of CTA."



Design Phase

up to 2010

Preparatory / Pre-construction Phase

2011-2014

Construction Phase

late 2014-2019

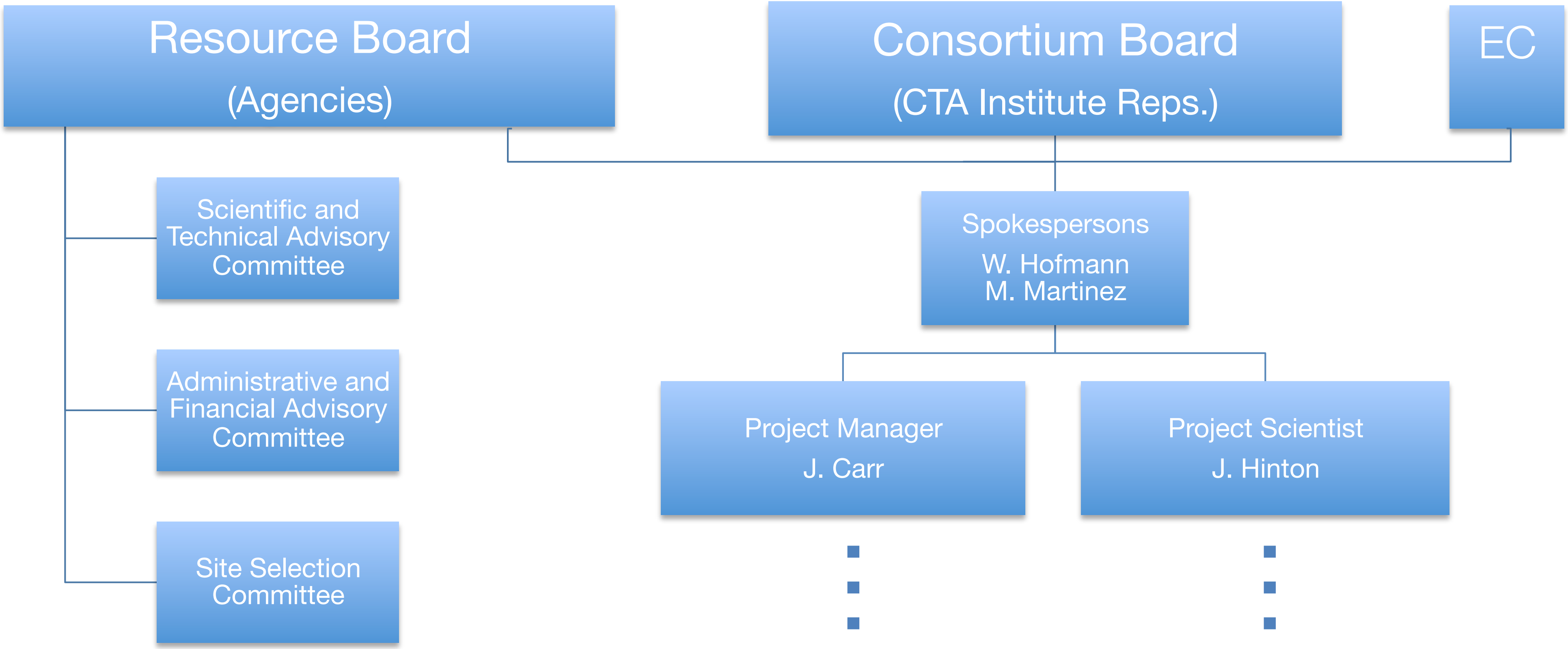
Operation Phase (up to 30 years)

Early science starting 2016/17

So far signed by

Argentina
Austria
Brazil
France
Germany
Italy
Japan
Namibia
Poland
South Africa
Spain
Switzerland
UK

CURRENT ORGANISATION



Resource Board
(Agencies)

Consortium Board
(CTA Institute Reps.)

EC

Scientific and Technical Advisory Committee

Administrative and Financial Advisory Committee

Site Selection Committee

Spokespersons
W. Hofmann
M. Martinez

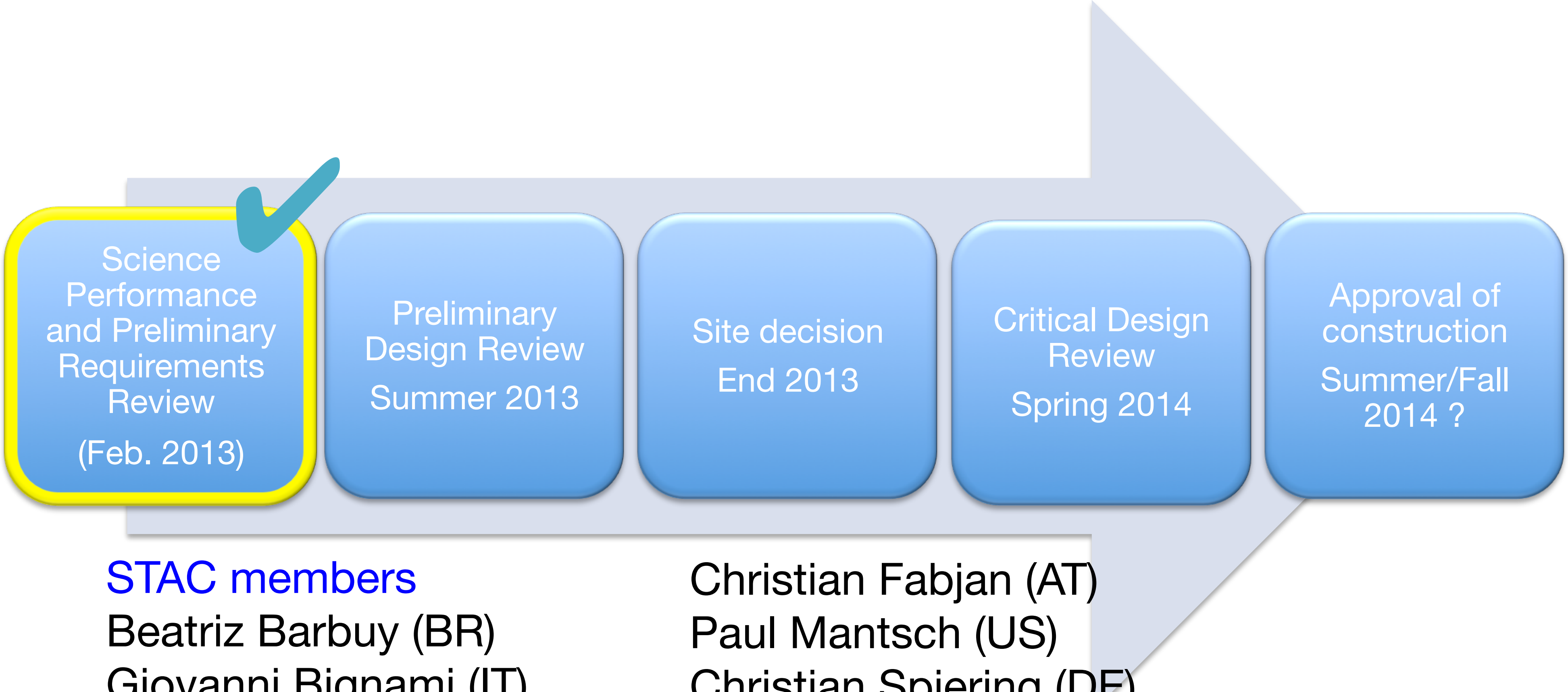
Project Manager
J. Carr

Project Scientist
J. Hinton

RB meets regularly
STAC performed in Feb. 2013 the “Science Performance and Preliminary Requirements Review”
AFAC meets regularly
SSC

MILESTONES TOWARDS APPROVAL

as agreed by Resource Board



Science Performance and Preliminary Requirements Review ✓

(Feb. 2013)

Preliminary Design Review

Summer 2013

Site decision

End 2013

Critical Design Review

Spring 2014

Approval of construction

Summer/Fall 2014 ?

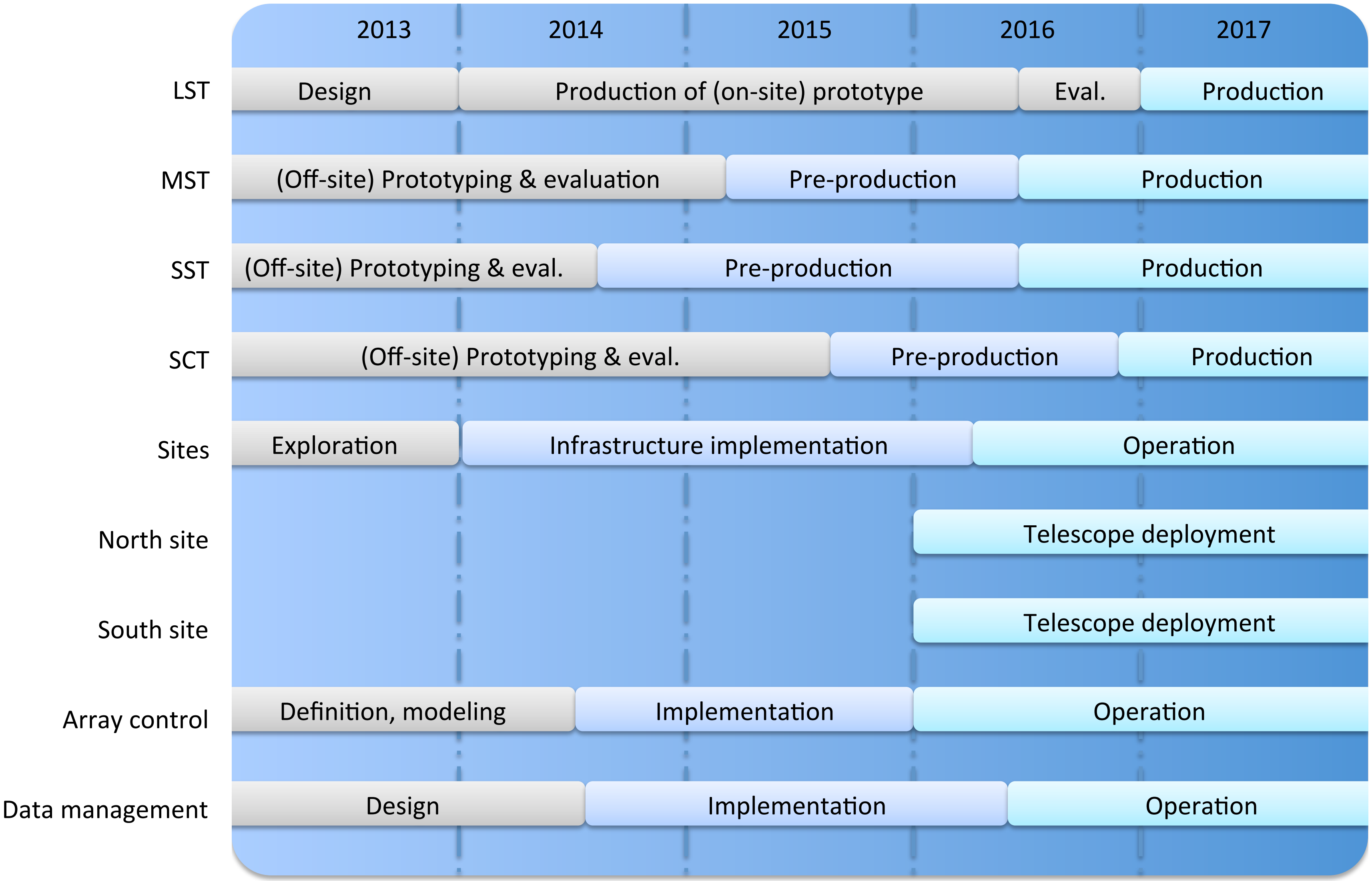
STAC members	
Beatriz Barbuy (BR)	Christian Fabjan (AT)
Giovanni Bignami (IT)	Paul Mantsch (US)
Roger Blandford (US)	Christian Spiering (DE)
Catherine Cesarsky (FR)	Matthias Steinmetz (DE)
John Ellis (UK/CERN)	Laurent Vigroux (FR)

ADDITIONAL “INTERNAL” REVIEWS

Review panels appointed by CTA management
Mix of internal and external members
Reviews typically last 2 days
Written reports

Feb. 2011	Review of MST Prototype
June 2011	Review of Camera Activities
Sept. 2011	Mirror Review
Oct. 2011	SST Review
Nov. 2011	LST Review
Dec. 2011	SITE review
Mar. 2012	CTA Requirements Review
Apr. 2012	Second Camera Review for CTA
May 2012	Management Review
July 2012	Second MST Review for CTA
Sept. 2012	Second Mirror Review for CTA
Oct. 2012	Second SITE Review
Feb. 2013	Second SST Review
Mar. 2012	Third SITE Review
Mar. 2013	Second LST Review

SCHEMATIC TIMELINE



2013 2014 2015 2016 2017

LST
Design
Production of (on-site) prototype
Eval.
Production

MST
(Off-site) Prototyping & evaluation
Pre-production
Production

SST
(Off-site) Prototyping & eval.
Pre-production
Production

SCT
(Off-site) Prototyping & eval.
Pre-production
Production

Sites
Exploration
Infrastructure implementation
Operation

North site
Telescope deployment

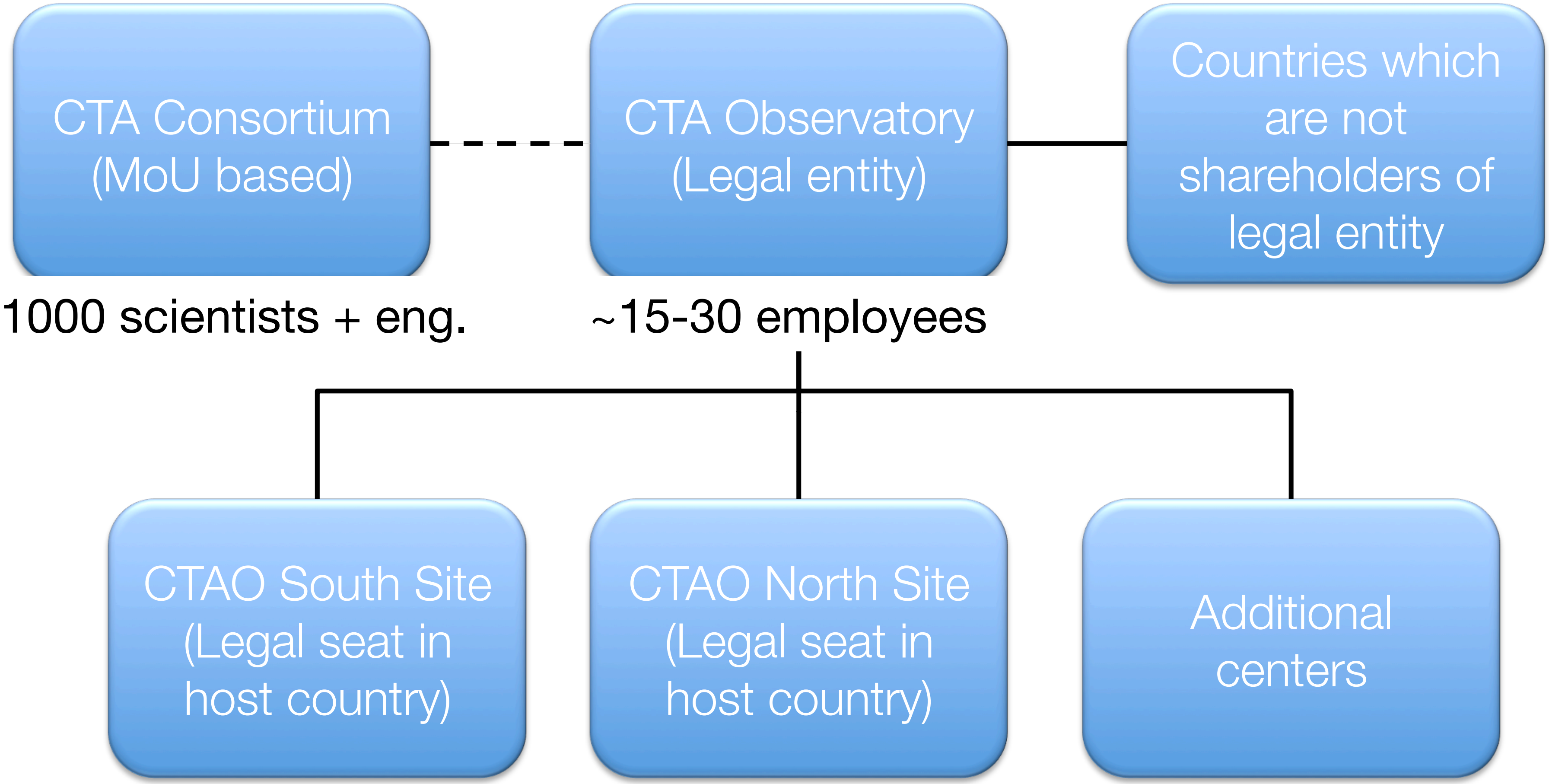
South site
Telescope deployment

Array control
Definition, modeling
Implementation
Operation

Data management
Design
Implementation
Operation

FUTURE LEGAL STRUCTURE, GOVERNANCE, ORGANIZATION

LEGAL SCHEME



CTA Consortium (MoU based)

>1000 scientists + eng.

CTA Observatory (Legal entity)

~15-30 employees

Countries which are not shareholders of legal entity

CTAO South Site (Legal seat in host country)

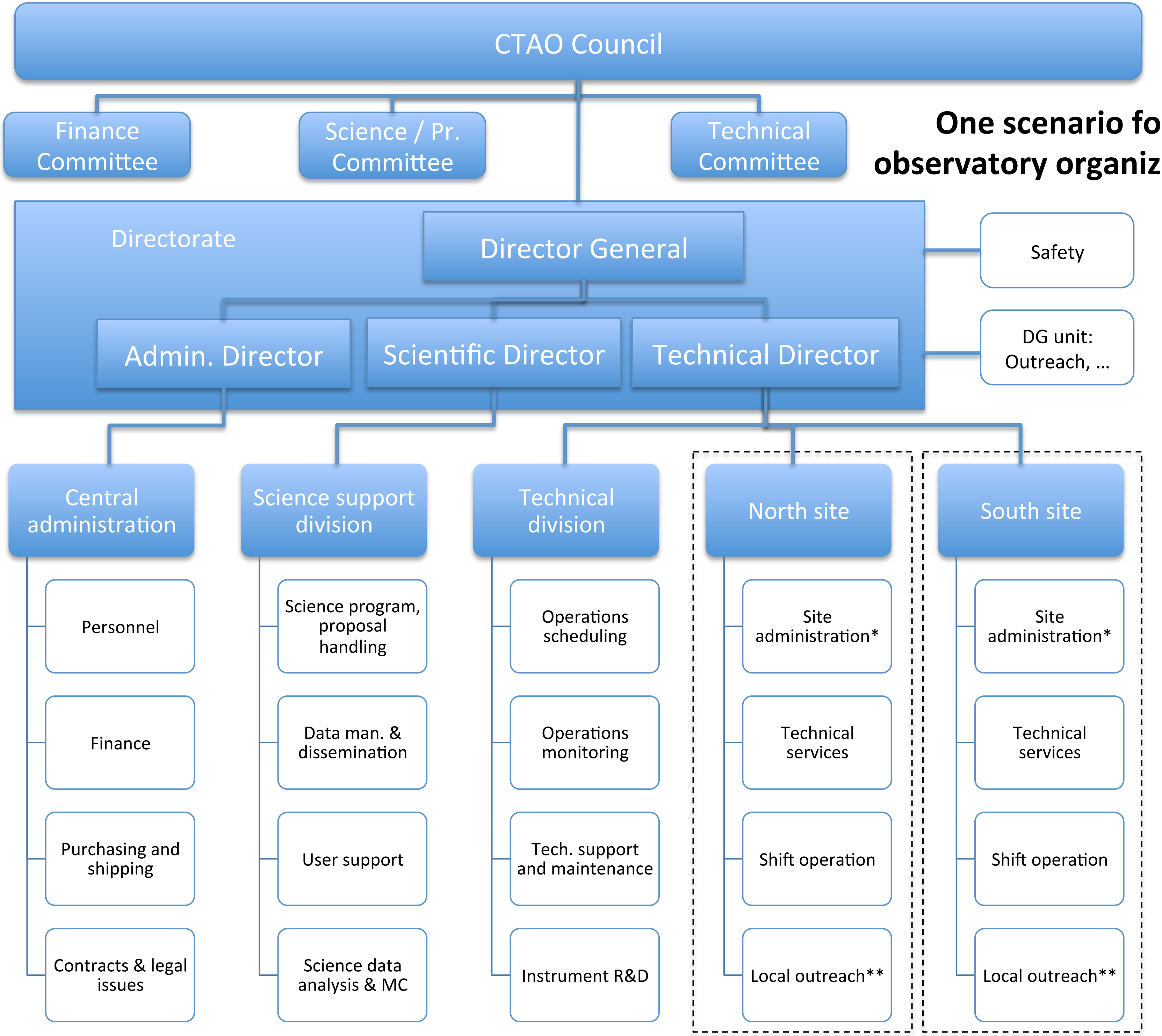
~35 employees

CTAO North Site (Legal seat in host country)

~20 employees

Additional centers

One scenario for observatory organization



CTAO Council

- Finance Committee
- Science / Pr. Committee
- Technical Committee

Directorate

- Director General
  - Admin. Director
  - Scientific Director
  - Technical Director

Safety

DG unit: Outreach, …

Central administration
- Personnel
- Finance
- Purchasing and shipping
- Contracts & legal issues

Science support division
- Science program, proposal handling
- Data man. & dissemination
- User support
- Science data analysis & MC

Technical division
- Operations scheduling
- Operations monitoring
- Tech. support and maintenance
- Instrument R&D

North site
- Site administration*
- Technical services
- Shift operation
- Local outreach**

South site
- Site administration*
- Technical services
- Shift operation
- Local outreach**

SITE SELECTION

SITES UNDER INVESTIGATION

Country	Location	Latitude	Elevation	Priority
Argentina	El Leoncito	31.7 S	~2700 m	medium
	San Antonio	24.0 S	~3600 m	high
Chile	ESO area	24.6 S	~2500 m	high
Namibia	Aar	26.7 S	~1700 m	high
	H.E.S.S.	23.3 S	~1800 m	medium
Mexico	San Pedro Martir	31.0 N	~2400 m	high
Spain	Teneriffe	28.3 N	~2300 m	high
US	Meteor Crater	35.0 N	~1700 m	high
	Yavapai Ranch	35.1 N	~1700 m	medium

not listed: low-priority sites
in India and Tibet

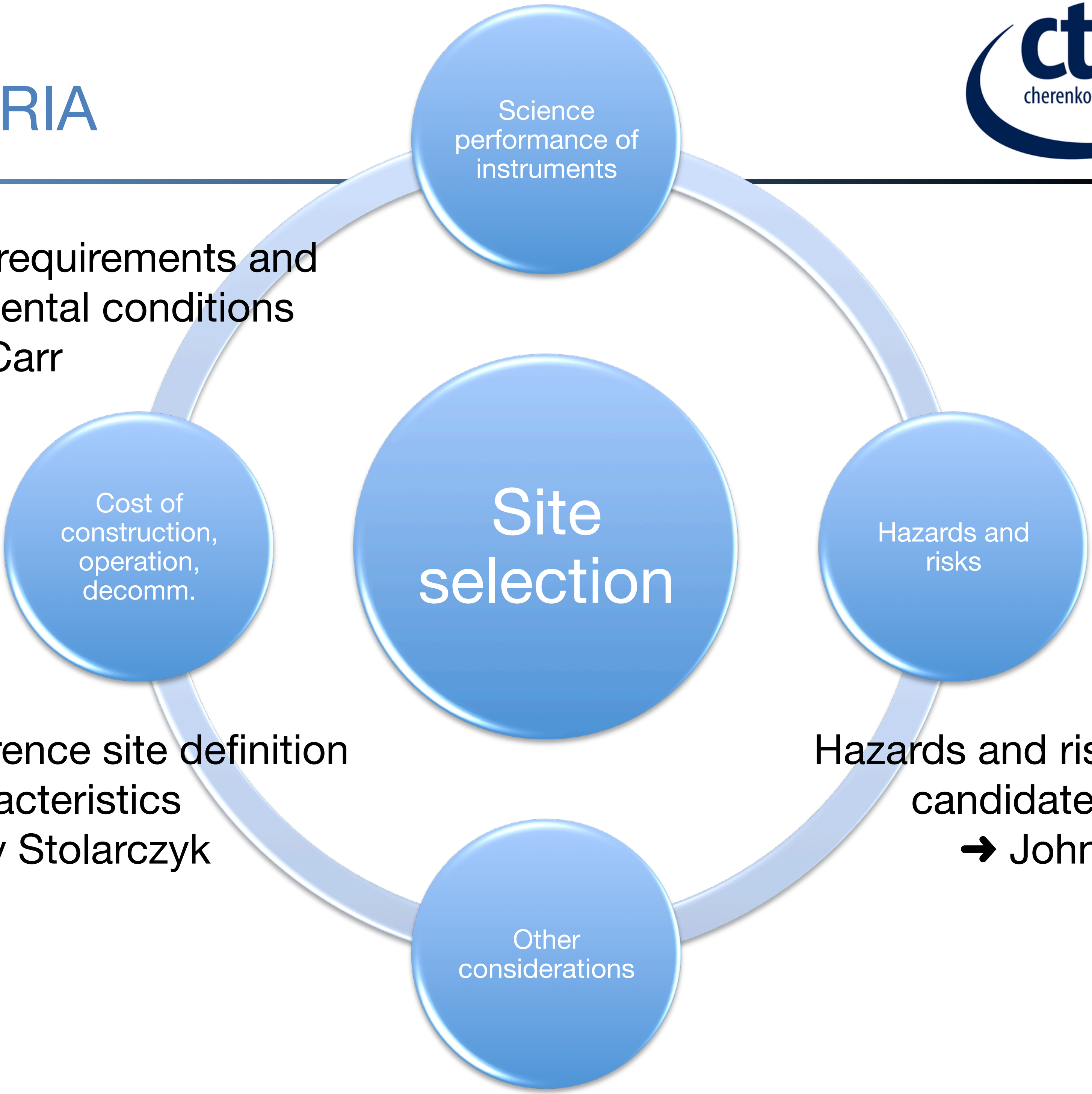
Basic requirements: 10 km^2 (S), 1 km^2 (N)
1500 – 3800 m elevation
>70% clear nights

SITE SELECTION

- Formal call for site proposals issued in late 2010
- Deadline July 2011 (South), January 2012 (North)
- Evaluation by SITE and SITE DEVELOPMENT WPs
- July 2012: RB installed Site Selection Committee (SSC)
- Nov. 2012: Definition of “site variables” and procedure
- April 2013: First meeting of SSC
- Fall 2013: SSC site recommendation to RB
- Winter 2013/2014: RB site decision

“The key criterion for the site choice should be to optimize the scientific output of the CTA observatory, within financial boundary conditions imposed by the agencies and countries funding CTA.”

CRITERIA



Site selection

Science performance of instruments

Cost of construction, operation, decomm.

Hazards and risks

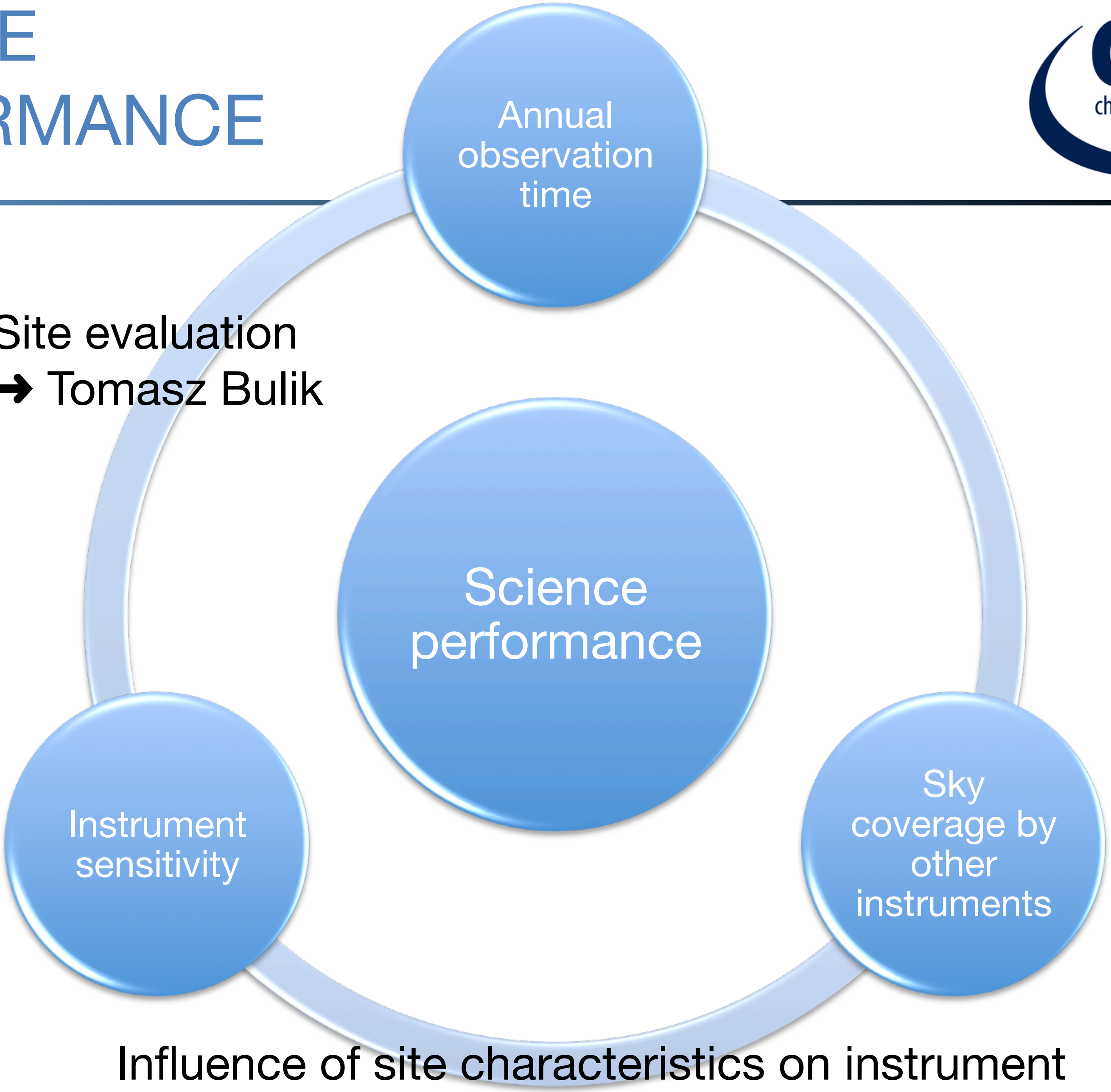
Other considerations

CTA site requirements and environmental conditions
➜ John Carr

CTA reference site definition and characteristics
➜ Thierry Stolarczyk

Hazards and risks at candidate sites
➜ John Carr

SCIENCE PERFORMANCE



Annual observation time

Science performance

Instrument sensitivity

Sky coverage by other instruments

Site evaluation
➜ Tomasz Bulik

Influence of site characteristics on instrument sensivity, multiwavelength environment
➜ Jim Hinton

FACTOR: ANNUAL OBSERVATION TIME

- Average number of cloud-free night hours
- Losses due to high wind, high humidity, …

Evaluation

- Archival ground data
- Remote sensing data analysis (typically covering 10 y)
- Own standardized instrumentation deployed at sites (typically covering 1 y)
- Atmospheric modeling (typically covering 10 y)

➜ Tomek Bulik

FACTOR: INSTRUMENT SENSITIVITY

Direct dependence on site

- Useful energy band depends on elevation
- Sensitivity depends (somewhat) on darkness of sky

➜ **Jim Hinton**

Cost constraints

- Sensitivity depends on # of telescopes

Instrument operation

- Effective sensitivity depends on efficiency of operation

FACTOR: COST

Implications of site choice on telescope construction cost

Wind loads, seismic loads, height, tax loads, …

Implications of site choice on infrastructure cost

Buildings, power, data networks, …

Implications of site choice on installation / commissioning decommissioning costs

Transport & access, height, local personnel, taxes/VAT, …

Implications of site choice on operating cost & operating efficiency

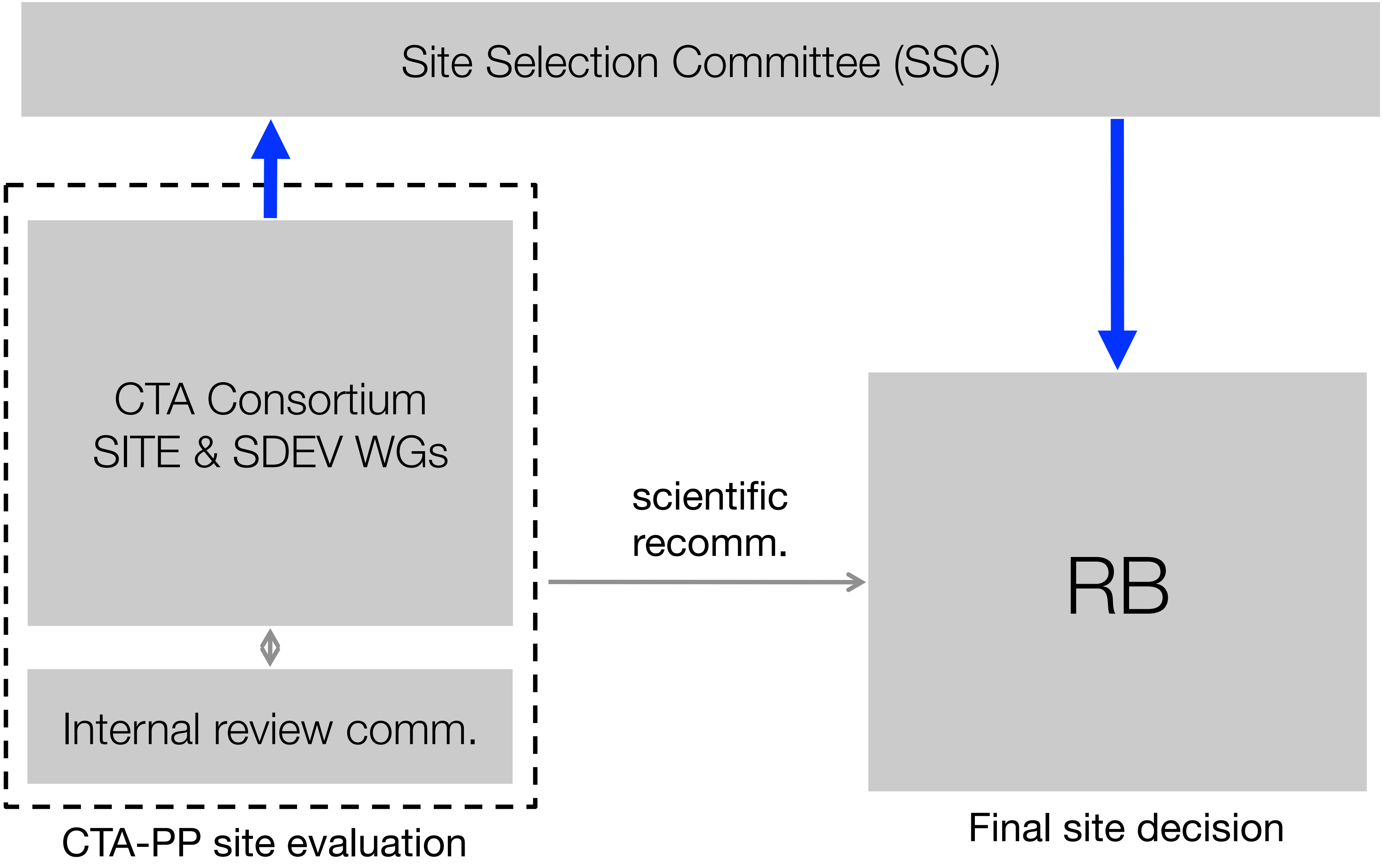
Local personnel, power, taxes/VAT, labor regulations, permits, …

For 20 years of operation, operating cost > construction cost
➜ hard to make reliable predictions over such periods

➜ **Thierry Stolarczyk**

SITE SELECTION PROCESS

AS AGREED BY RB



Site Selection Committee (SSC)

CTA Consortium
SITE & SDEV WGs

Internal review comm.

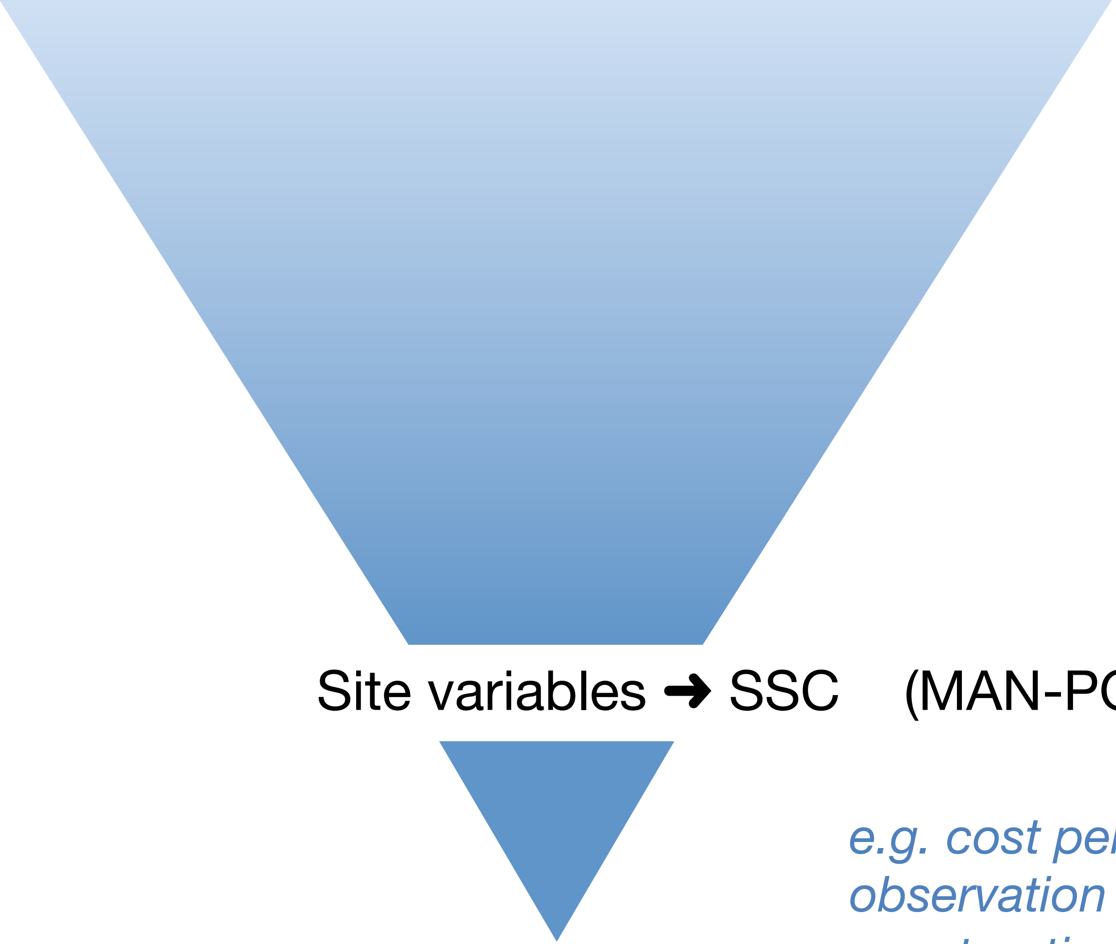
CTA-PP site evaluation

scientific
recomm.

RB

Final site decision

SITE VARIABLES



Site measurements, data, parameters

Site variables ➜ SSC (MAN-PO/121004a)

Figure(s) of merit

e.g. cost per 10000 nominal-sensitivity observation hours, including construction – boosted by (i) clear skies, (ii) high sensitivity, (iii) low constr. cost, (iii) low operating cost

SITE VARIABLES

“Hard variables”

Science performance

- Average annual observation time
- Instrument sensitivity
- Multiwavelength and multimessenger coverage

Cost (relative to Reference Site)

- Instrument construction costs
- Infrastructure construction costs
- Annual operating costs
- Decommissioning costs

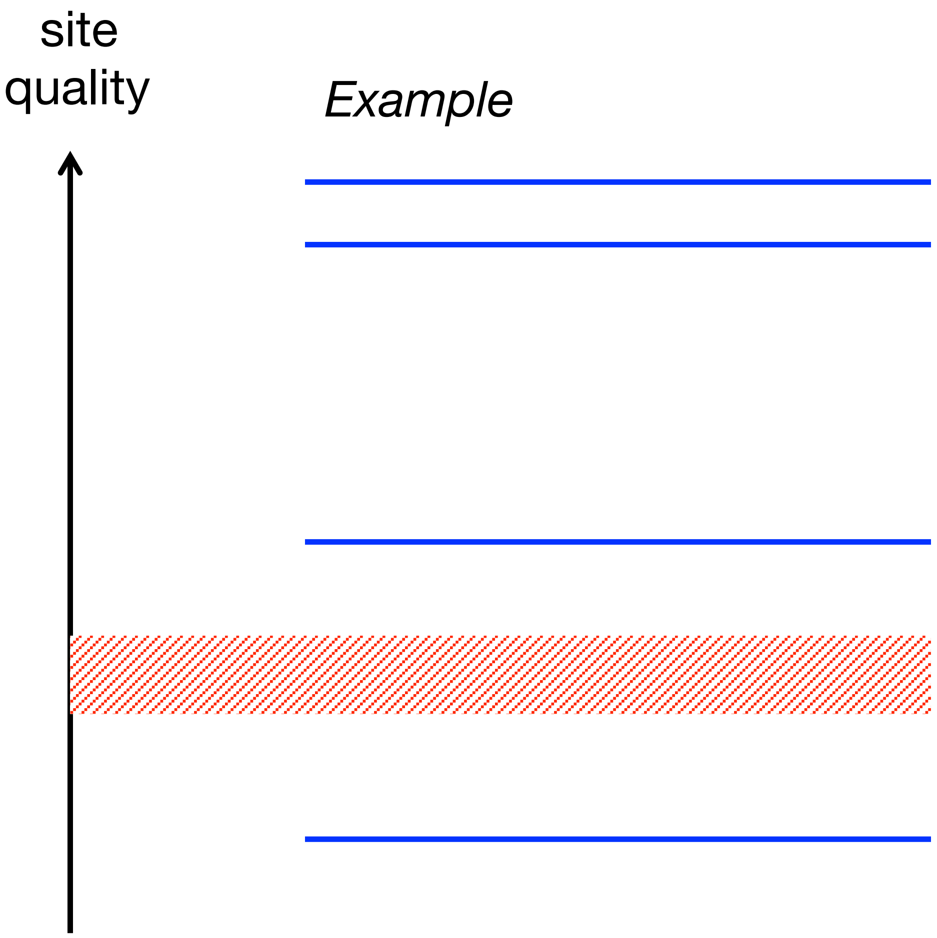
“Soft variables”

Hazards and risks

- Hazards to be considered for personnel
- Risks to be considered for instrument/facility

Other issues

SSC / CTA SHOULD PROVIDE SITE RANKING



site A: top

site B: almost as good

site C: clearly no in top group, but acceptable as site

site D: below cut

INTEGRATED SENSITIVITY

CTA operates mostly in background dominated regime

$F_{min} \sim T^{-1/2}$

➜ 10% difference in available observation time translates into 5% difference in sensitivity per source

Sensitivity depends on # of telescopes, height, etc.

Very very roughly

$F_{min} \sim N_{tel}^{-0.7}$

➜ 10% difference in cost translates into 7% difference in sensitivity per source at constant construction budget

➜ Influence of height: depends on energy domain ➜ JH

INTEGRATED SENSITIVITY

In an ideal world, given a certain budget:
Optimize minimal detectable flux per average source, for a given sum of construction + operation costs (for 1-2 decades)

However, the world is not ideal
In the long run operating costs tend to bother more than construction costs, but savings in anticipated operating costs cannot be translated into more telescopes, extrapolated operating costs have non-negligible uncertainty, …
➜ Balance between base sensitivity, construction costs and annual operating costs non-trivial and depends on non-scientific factors

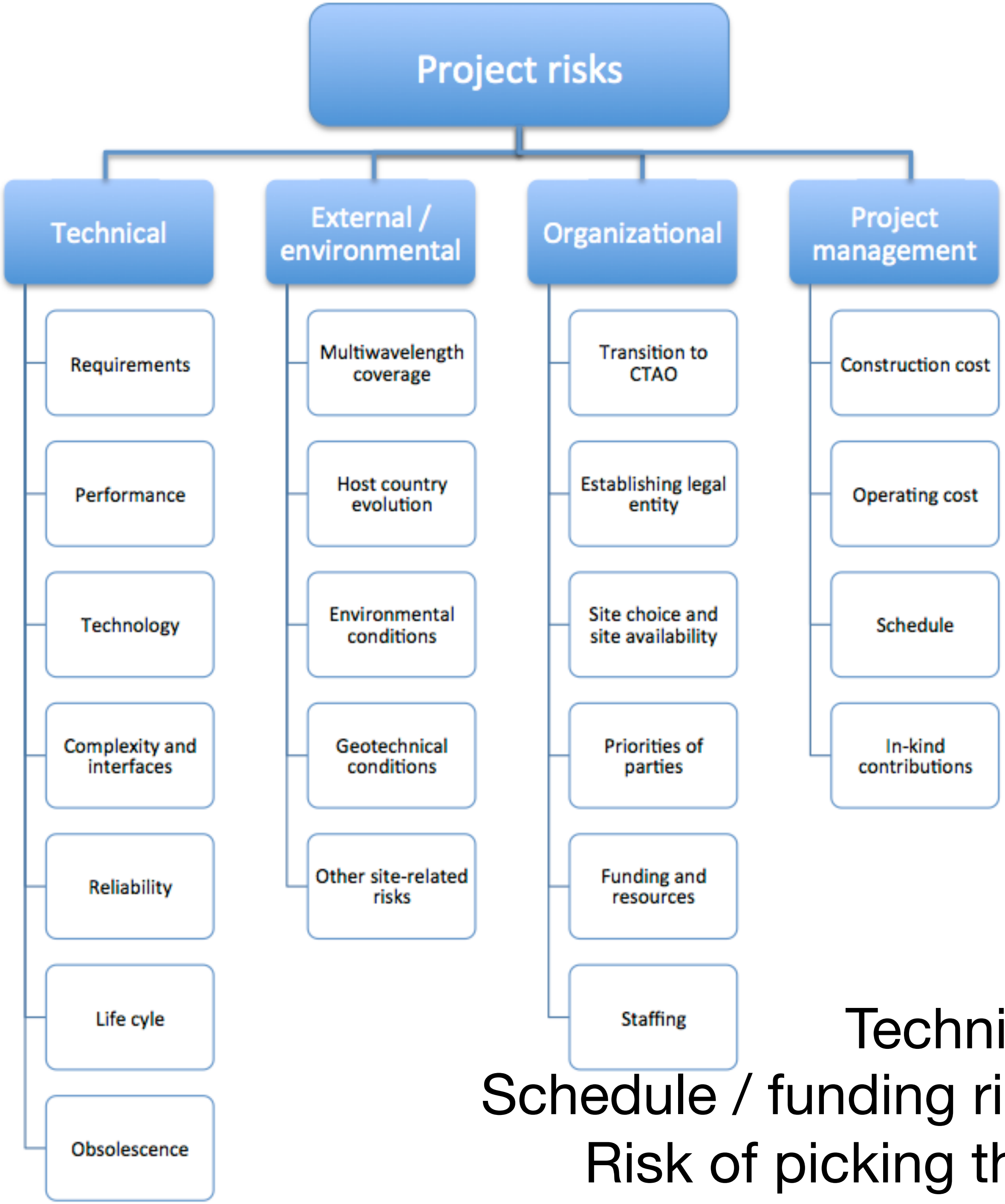
In my personal view:

- Differences between “good” sites are not dramatic
- For overall science output, probably more important to avoid sites with significant risk of events or conditions which impact construction or efficiency of operation (e.g. due to environmental conditions, lack of qualified personnel, …)

FEASIBILITY AND RISKS

➜ JOHN CARR

Well-known technology:
e.g. HESS 4 x 12 m (~MST)
1 x 28 m (>LST)



Project risks

Technical
- Requirements
- Performance
- Technology
- Complexity and interfaces
- Reliability
- Life cyle
- Obsolescence

External / environmental
- Multiwavelength coverage
- Host country evolution
- Environmental conditions
- Geotechnical conditions
- Other site-related risks

Organizational
- Transition to CTAO
- Establishing legal entity
- Site choice and site availability
- Priorities of parties
- Funding and resources
- Staffing

Project management
- Construction cost
- Operating cost
- Schedule
- In-kind contributions

Technical risks: small
Schedule / funding risks: significant
Risk of picking the "wrong" site

BOTTOM LINE

- Organization: evolving in constant contact with agency committees
- Technical implementation: based on long-term experience; telescope prototypes under construction
- Funding: based on statements in RB, funding is plausible
- Schedule: tight, in the short term driven by site decision and site development, and by establishment of a legal and project management structures