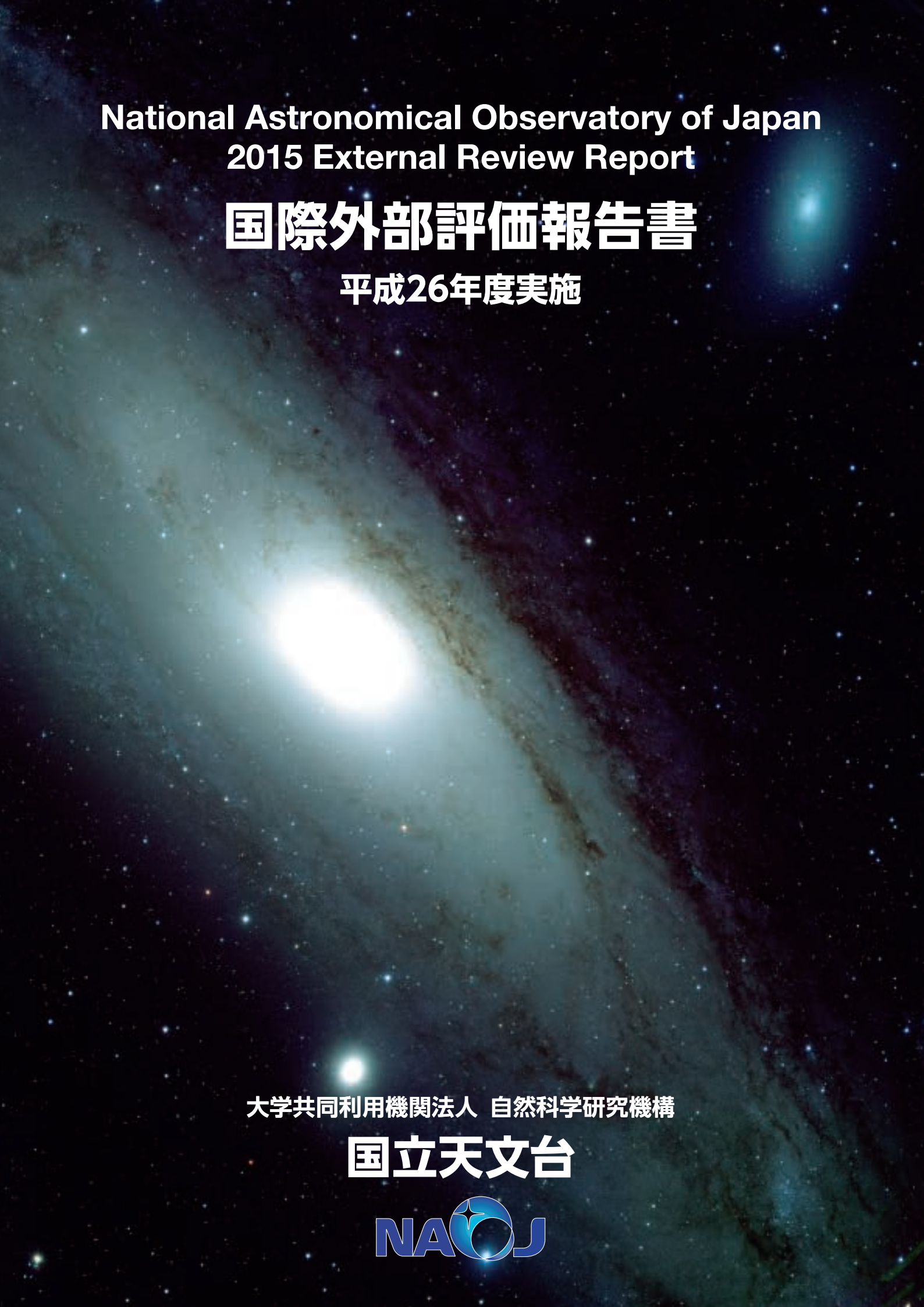
National Astronomical Observatory of Japan
2015 External Review Report

国際外部評価報告書

平成26年度実施



大学共同利用機関法人 自然科学研究機構

国立天文台

NAOJ

National Astronomical Observatory of Japan
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大学共同利用機関法人　自然科学研究機構

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Observatory of Japan

Contents 目次

◆ 表紙写真／国立天文台ハワイ観測所のすばる望遠鏡に 2012 年 8 月から搭載されている、超広視野主焦点カメラ Hyper Suprime-Cam（ハイパー・シュプリーム・カム：HSC）がとらえたアンドロメダ銀河 M31。

◆ 裏表紙下の写真／すばる望遠鏡に当初（1999 年 7 月）から搭載されている主焦点カメラ Suprime-Cam（左下、中央）と、HSC（右）がとらえた M31 の視野の比較。黄色い枠は Suprime-Cam の各写真の撮影領域を、左上は満月の典型的な見かけの大きさを示す。すばる望遠鏡と HSC の組み合わせで、観測の効率がさらに大きく高まった。

国際外部評価によせて

国立天文台長　林 正彦

2015 年の 2 月に、国立天文台では国際外部評価を実施しました。この冊子は、その評価報告書です。その要旨第一文では、「過去 5 年間における最も重要な進展は、日本が主要な国際天文プロジェクトに参画するようになり、高い成功を収めるようになったことである。」と書かれています。

これは主としてアルマと TMT のことを言っています。それは、このふたつのプロジェクトが過去 5 年間で大きく進展したからであり、またそれ以前のプロジェクトとは質的に異なって本質的な国際化を果たしたからです。すばる望遠鏡は、観測施設を海外の最適地に設置するという形で、それまでの日本の天文学界が経験したことのないプロジェクトでした。しかし、その建設と運営は日本一国で実現可能なものでした。これに対し、アルマや TMT は総予算規模もすばるの数倍となり、計画段階から建設・運用に至るまで、国際的な枠組みのなかで進めることとなりました。このような真に国際的な大型プロジェクトのなかで、日本としてふさわしい役割を果たし、成果を挙げていけるかどうかは全く未知数でありました。その意味で、今回の国際外部評価において、上述のようなコメントをいただいたことは、まことに喜ばしい限りであります。

国立天文台は、1988 年 7 月 1 日に、東京大学東京天文台と緯度観測所を改組転換し、名古屋大学空電研究所の一部を移管して発足しました。早いもので発足からすでに 27 年の歳月が流れました。この間、上述の 3 大プロジェクト以外にも、野辺山太陽電波観測所のヘリオグラフ、岩手県水沢・東京都父島・鹿児島県入来・沖縄県石垣に設置した天文広域精測望遠鏡 VERA、重力波観測装置 TAMA300、石垣島天文台等が、新たな望遠鏡・観測施設となりました。また現在は、東京大学宇宙線研究所、高エネルギー加速器研究機構と共同で、岐阜県神岡に大型低温重力波望遠鏡 KAGRA を建設中でもあります。さらに衛星搭載の望遠鏡を使った観測活動も活発に行われ、太陽観測衛星「ようこう」「ひので」、スペース VLBI 望遠鏡である「はるか」、月探査衛星「かぐや」は代表例であります。シミュレーション分野では、スーパーコンピューター・専用計算機の導入が達成されました。

国立天文台では、これらの装置を全国の国公私立大学及び研究機関の研究者に提供して、共同利用・共同研究を活発に実施し、我が国の天文学の振興に貢献すると共に、海外の研究者にも門戸を開いてきました。これらも含めて、この 27 年間で国立天文台は世界最高レベル

の観測・研究装置を有する国際研究機関となりました。国立天文台がこのような大きな飛躍を遂げることができましたのも、多くの諸先輩並びに文部省および文部科学省のご尽力、三鷹市を始めとして研究施設を設置させていただいている国内外の自治体のご理解とご支援、さらには全国の大学・研究所、そして国内外の研究者のご支援の賜物であります。この場をお借りして、感謝申し上げます。

なお、2004 年より国立天文台は他の 4 つの大学共同利用機関と統合されて、自然科学研究機構の一員となっていますが、その役割に変更はありません。その役割を自ら確認する意味で、2014 年には国立天文台の理念を以下のように制定しました。① 私たちのめざす姿は、「宇宙の謎に挑む国立天文台」です。② 私たちが成すべきことは、「知の地平線を拡げるため、大型天文研究施設を開発・建設し、共同利用に供する」こと、「多様な大型施設を活用し、世界の先端研究機関として天文学の発展に寄与する」こと、「天文に関する成果・情報提供を通じて、社会に資する」ことの 3 本柱です。③ 私たちが社会に提供するものは、「未知の宇宙の解明と、新しい宇宙像の確立」、「研究成果の社会への普及・還元と、未来世代への夢の伝承」、「世界を舞台に活躍する次世代研究者」です。

また国立天文台を含む東アジア諸国の主要天文台は、2005 年に「東アジア中核天文台連合」を発足させました。さらに 2014 年には「東アジア天文台」を発足させて、東アジアにおける今後の国際協力を加速するための基本的枠組みを作りました。現在進めている各プロジェクトと、東アジアを中心に進める将来のプロジェクトの進展によって、現代天文学の大きなテーマである「太陽系外惑星の探査と宇宙における生命存在の確認」「ダークエネルギーおよびダークマターの研究」「ブラックホール等特異天体の解明」等の研究をさらに推進させることができます。

皆様には、今後も引き続き国立天文台の活躍にご支援とご期待をお願いいたします。

Presenting the Findings of the External Review

NAOJ Director General Dr. Masahiko Hayashi

In February of 2015, an external review was conducted at NAOJ. This booklet is the Evaluation Report from the External Review. The first sentence of the evaluation report states, “The most significant development of the last five years must be the growing and highly successful Japanese participation in major international astronomical projects.”

This refers primarily to ALMA and TMT. That is because these two projects have progressed greatly in the past 5 years, and because they are qualitatively different from previous projects in that they are based fundamentally on internationalization. The Subaru Telescope was established as an observational facility in the best observational site available overseas, a type of project for which the Japanese astronomy community had no prior experience. But its construction and operation was the upper limit of what Japan could achieve as a single country. In contrast, the total budgets for ALMA and TMT are several times that of the Subaru Telescope. So these projects are proceeding within an international framework from the planning stage, through construction, and into operation. There were many unknowns involved in whether or not Japan could succeed in fulfilling an important role within these kinds of truly international, large projects. From this point of view, it is genuinely gratifying to have received the above comment in this external review.

NAOJ was formed on July 1, 1988 through the reorganization and merger of the Tokyo Astronomical Observatory, University of Tokyo; the International Latitude Observatory of Mizusawa; and part of the Research Institute of Atmospherics, Nagoya University. The 27 years since the founding of NAOJ have passed quickly. In this time, beyond the 3 large projects mentioned above, new telescopes and instruments have been developed including Nobeyama Solar Radio Observatory’s Radioheliograph; VERA (VLBI Exploration of Radio Astrometry) Stations established at Mizusawa in Iwate Prefecture, Chichi-jima in Tokyo, Iriki in Kagoshima Prefecture, and Ishigaki-jima in Okinawa Prefecture; the gravitational wave detector TAMA300; and Ishigaki-jima Astronomical Observatory. And we are now cooperating with ICRR (the Institute for Cosmic Ray Research, University of Tokyo) and KEK (High Energy Accelerator Research Organization) on the construction of KAGRA (Kamioka Gravitational wave detector, Large-scale Cryogenic Gravitational wave Telescope) in Kamioka in Gifu Prefecture. In addition, we are actively participating in research utilizing space-borne observing instruments as exemplified by the Solar Observatory satellites “YOHKOH” and “HINODE”; the space VLBI telescope “HALCA”; and the Lunar Explorer “KAGUYA.” In the field of simulations, dedicated computers for astronomical research and supercomputers have been successfully introduced.

At NAOJ, we offer these instruments to researchers at public and private universities and research institutes throughout Japan through open use and collaborative research. While contributing to the advancement of Japanese astronomy, we also open the door for overseas researchers. Considering all of this, we can say with certainty that over these 27 years NAOJ has become an international research institute with world leading observational and research facilities. The fact that NAOJ has been able to take these great strides forward is the result of the efforts made by many of our predecessors, MEXT (the Ministry of Education, Culture, Sports, Science, and Technology) and the previous Ministry of Education, Science, Sports and Culture; the support and understanding of the municipalities, first and foremost Mitaka City, where we have been allowed to establish research facilities both in Japan and around the world; the support of Universities and research institutes throughout Japan; and the support of domestic and international researchers. We would like to take this occasion to thank all of them.

In 2004, NAOJ and 4 other inter-university research institutes were integrated into the Inter-University Research Institute Corporation, National Institutes of Natural Sciences. But this did not change our role. To reaffirm this role, in 2014 NAOJ codified our Philosophy: I) Our Vision is “to be innovators striving to solve the mysteries of the Universe.” II) Our Mission has 3 pillars: to develop and construct large-scale cutting-edge astronomical research facilities and promote their open access aiming to expand our intellectual horizons; to contribute to the development of astronomy as a world leading research institute by making the best use of a wide variety of large-scale facilities; and to bring benefits to society through astronomy public outreach. III) Our Products/Deliverables are: to explore the unknown Universe and provide new insight into astronomy; to make our research outcomes widely known to society and pass on our dreams to future generations; and to mentor next-generation researchers for their role on the world-stage.

Internationally, EACOA (the East Asian Core Observatories Association) was founded in 2005 by the major observatories in East Asia, including NAOJ in Japan. Then in 2014, the East Asian Observatory was established to provide a framework for facilitating future international cooperation in East Asia. Through the projects which we are now pursuing and the development of future projects which we will pursue with a focus on East Asia, it will be possible to further advance the major themes of modern astronomy: the search for extra-solar planets and confirmation of the presence or absence of life in the Universe; research into dark energy and dark matter; clarification of the peculiar celestial bodies such as black holes; and other mysteries of the Universe.

We would like to request everyone’s continued belief in and support for NAOJ’s activities.

外部評価委員会による評価レポート要旨（和訳）

平成２７年８月

過去５年間における最も重要な進展は、日本が主要な国際天文プロジェクトに参画するようになり、高い成功を収めるようになったことである。このことは世界中の天文学に利益をもたらし、日本にも恩恵をもたらすであろう。日本がいまや TMT などの大規模プロジェクトにおいて国際的指導者の役割を果たしていることは特筆すべき成長といえる。評価委員会は国立天文台のこのような国際的な活躍、特に３つの基幹プロジェクト：ALMA、すばる望遠鏡、TMT における活躍を祝福したい。同時に、国立天文台が東アジア諸国との連携を強化している点も歓迎する。このこともまた、世界中の天文学に利益をもたらすであろう。

我々は、世界の天文コミュニティにおいて日本がその国際性をしっかりと維持し、適切なリーダーシップを発揮することが大切であると考えている。そのために国立天文台が最優先すべきは、国際プロジェクトであろう。つまり、国立天文台でなければ達成できないプロジェクトと、日本または東アジアの他の研究組織が達成できるプロジェクトとをしっかり区別すべきだ。国立天文台が日本の大学や東アジアの研究組織とすでに良好な関係を築いている点は、望ましいことである。国立天文台には、創造性やイノベーション、新技術を用いた実験の機会が十分にある小規模プロジェクトも（おそらく大学と共同で）継続して欲しい。しかし、財源と人材は限られているため、今後はプロジェクトの優先順位を明確にすることが求められるだろう。この点については、各章で詳しく書いている。また、プロジェクト長･センター長･研究部主任は、自分のグループの人件費管理を全て任されていなくても、人件費総額は知っておくとよいだろう。

国立天文台はまた、日本の天文学研究においてリーダーシップを発揮しつつ、多数の理工系大学院生や若手研究者の教育を支援することで、台内および大学の教職員へと送り出してきた。世界中の主要な天文台に見られるように、観測所としてのサービスを提供する役割と、研究と若手教育の両方を担う一流スタッフを雇用する責務は対立する関係にある。これについては簡単な解決策はないが、重要なのはスタッフが研究に従事し続けることである。ポスドクを雇用する財源は確保されるべきだ。この点、国立天文台内に強力な理論研究部があることは良いことである。

欧米では広く認められていることだが、研究においてもビジネスにおいても、多様性があるグループは多様性がないグループよりも強さと柔軟性を併せ持ち、成功しやすい。評価委員会は、女性研究者を積極的に採用する国立天文台の最近の取組を歓迎する。国立天文台がさらに女性限定の公募を行い、より多くの優秀な女性研究者を雇用することを推奨する。また、今後は職員構成の男女別内訳も示してほしい。さらに、職員の国際化（文化的多様性）の強化を勧める。TMT のような大規模国際プロジェクトが展開する時代においては、この点が

さらに重要になるだろう。すでに東アジアの天文組織が結束するために英語が共通言語として使われており、職員の国際化が進めば国立天文台でも英語の使用頻度が増すだろう。

外部評価当日の会場の様子

若手研究者ヒアリングの様子

外部評価委員会委員名簿

◆委員長

Jocelyn Bell Burnell （ジョスリン・ベル・バーネル）	英国 オックスフォード大学・客員教授

◆副委員長

岡村 定矩 （おかむら さだのり）	法政大学・教授 ／ 東京大学・名誉教授

◆委員

David Richard Silva （デービッド・シルバ）	アメリカ国立光学天文台・台長
James M. Stone （ジェームズ・ストーン）	米国 プリンストン大学・教授
Sami K. Solanki （サミ・ソランキ）	ドイツ マックス・プランク太陽システム研究所・所長 ／ 韓国 慶熙大学校・特別栄誉教授
Anthony J. Tyson （アンソニー・タイソン）	米国 カリフォルニア大学デービス校・特別栄誉教授
Paul T. P. Ho （ポール・ホ）	台湾中央研究院天文及天文物理研究所・特別栄誉研究員
Floor van Leeuwen （フロア・ヴァン・ルーウェン）	英国 ケンブリッジ大学・上級研究技師
大向 一行 （おおむかい かずゆき）	東北大学・教授
久野 成夫 （くの なりお）	筑波大学・教授
土居 守 （どい まもる）	東京大学・教授
堂谷 忠靖 （どうたに ただやす）	宇宙航空研究開発機構 宇宙科学研究所・教授
横山 央明 （よこやま たかあき）	東京大学・准教授

（以上１３名）

外部評価委員と国立天文台執行部

（後列）髙見、郷田、堂谷、久野、土居、林、渡部、横山、大向

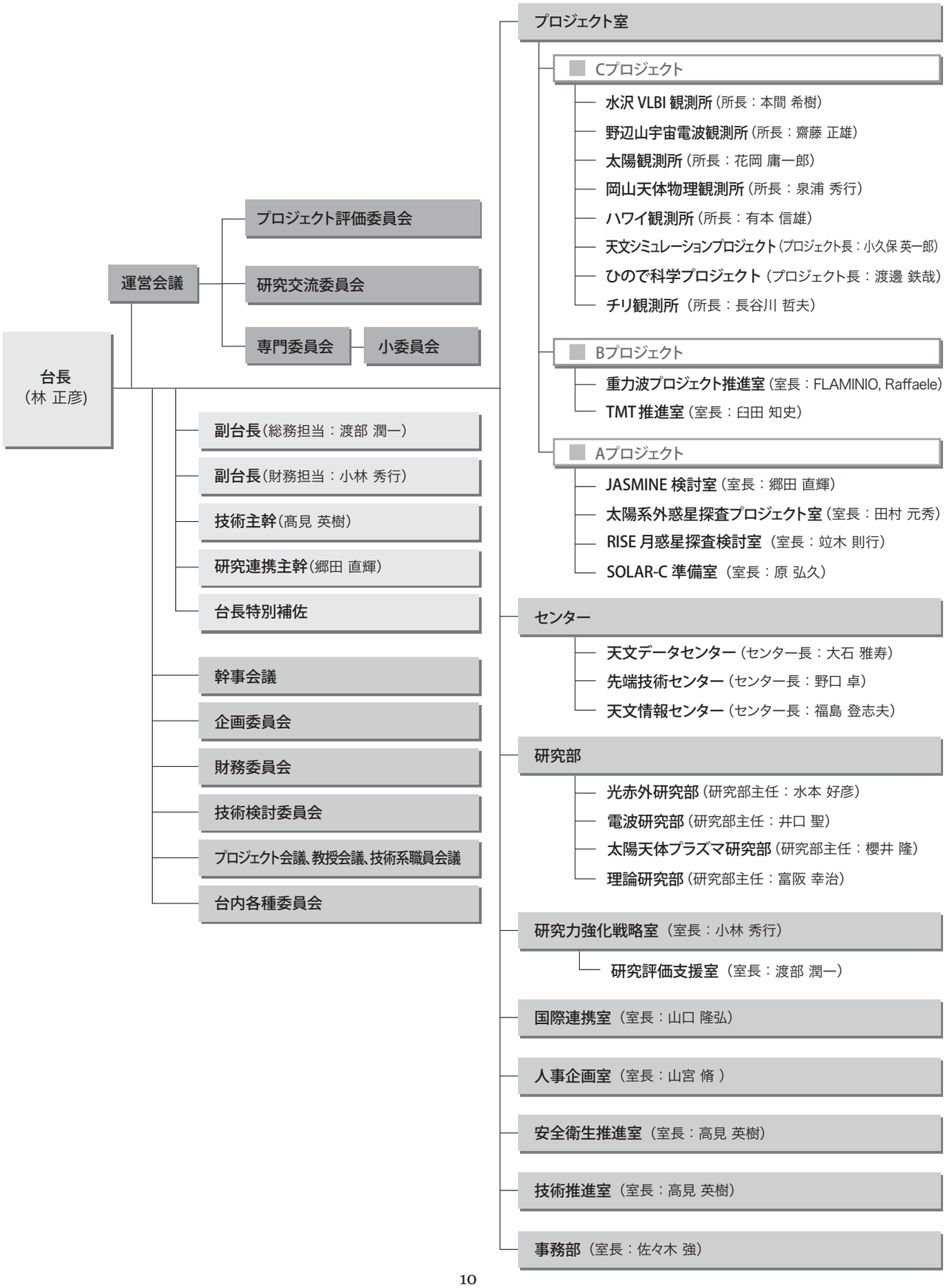
（前列）ヴァン・ルーウェン、ソランキ、シルバ、岡村、ベル・バーネル、ホ、タイソン、ストーン

Review Committee and NAOJ Directorate

Back row: Takami, Gouda, Dotani, Kuno, Doi, Hayashi, Watanabe, Yokoyama, Omukai

Front row: van Leeuwen, Solanki, Silva, Okamura, Bell Burnell, Ho, Tyson, Stone

組織図


台長
(林 正彦)
運営会議
プロジェクト評価委員会
研究交流委員会
専門委員会
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研究連携主幹(郷田 直輝)
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Cプロジェクト
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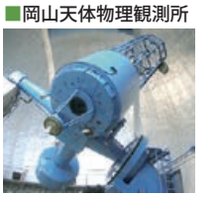
野辺山宇宙電波観測所(所長：齋藤 正雄)
太陽観測所(所長：花岡 庸一郎)
岡山天体物理観測所(所長：泉浦 秀行)
ハワイ観測所(所長：有本 信雄)
天文シミュレーションプロジェクト(プロジェクト長：小久保 英一郎)
ひので科学プロジェクト(プロジェクト長：渡邊 鉄哉)
チリ観測所(所長：長谷川 哲夫)
Bプロジェクト
重力波プロジェクト推進室(室長：FLAMINIO, Raffaele)
TMT 推進室(室長：臼田 知史)
Aプロジェクト
JASMINE 検討室(室長：郷田 直輝)
太陽系外惑星探査プロジェクト室(室長：田村 元秀)
RISE 月惑星探査検討室(室長：竝木 則行)
SOLAR-C 準備室(室長：原 弘久)
センター
天文データセンター(センター長：大石 雅寿)
先端技術センター(センター長：野口 卓)
天文情報センター(センター長：福島 登志夫)
研究部
光赤外研究部(研究部主任：水本 好彦)
電波研究部(研究部主任：井口 聖)
太陽天体プラズマ研究部(研究部主任：櫻井 隆)
理論研究部(研究部主任：富阪 幸治)
研究力強化戦略室(室長：小林 秀行)
研究評価支援室(室長：渡部 潤一)
国際連携室(室長：山口 隆弘)
人事企画室(室長：山宮 脩)
安全衛生推進室(室長：高見 英樹)
技術推進室(室長：高見 英樹)
事務部(室長：佐々木 強)

研究施設

国立天文台岡山
■岡山天体物理観測所



国立天文台野辺山
■野辺山宇宙電波観測所

国立天文台水沢
■水沢 VLBI 観測所・VERA 水沢観測局

32m 電波望遠鏡
（手前が高萩アンテナ、奥が日立アンテナ）
■水沢 VLBI 観測所・茨城観測局

VLBI・7局（VERA4局を含む）
■水沢 VLBI 観測所・山口観測局

■水沢 VLBI 観測所・VERA 入来観測局

■水沢 VLBI 観測所・
鹿児島観測局

■水沢 VLBI 観測所・
VERA 石垣島観測局

■石垣島天文台

■水沢 VLBI 観測所・
VERA 小笠原観測局

国立天文台三鷹（本部）
三鷹キャンパス

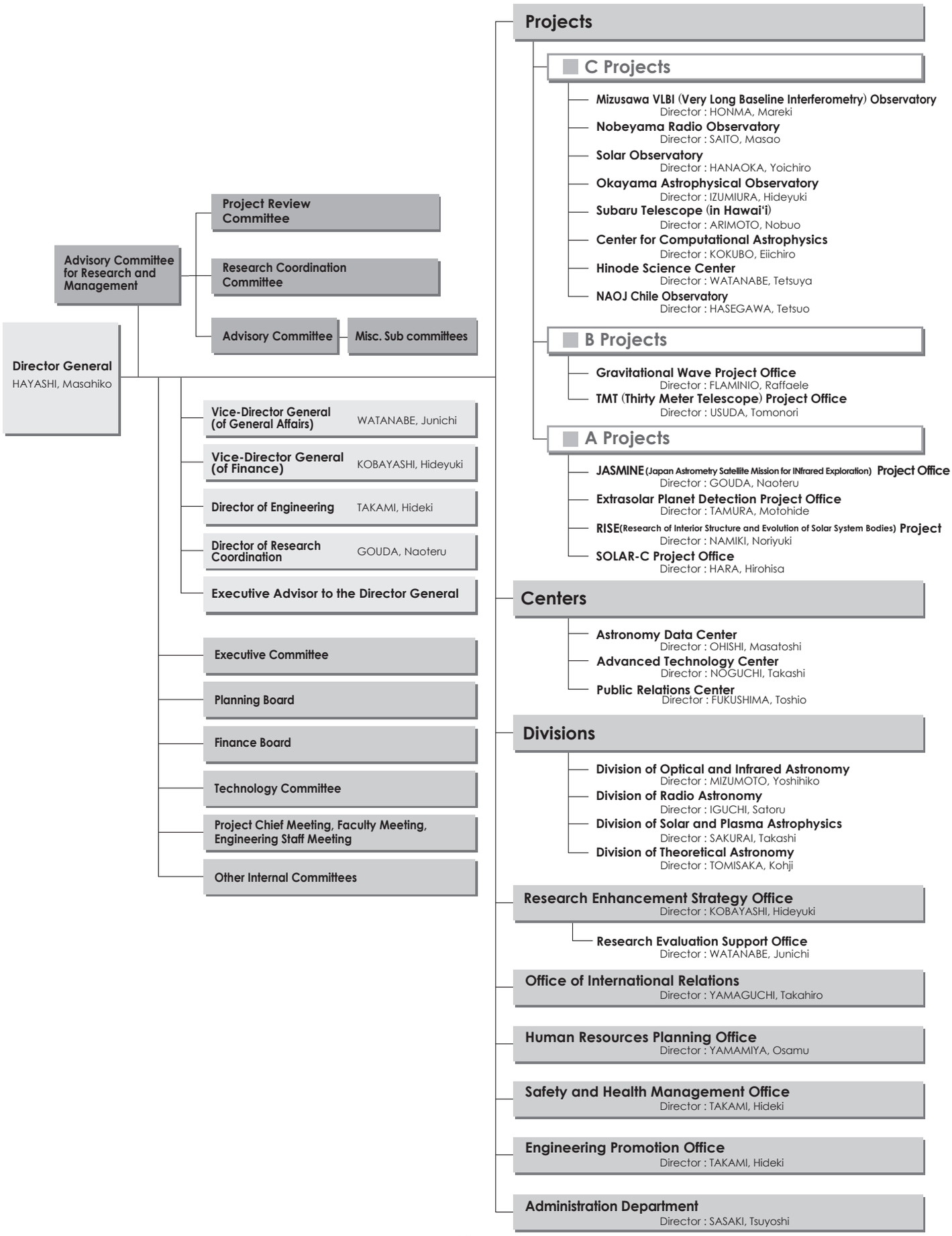
国立天文台チリ
■チリ観測所
ALMA（アタカマ大型ミリ波サブミリ波干渉計）

国立天文台ハワイ
■ハワイ観測所

ヒロ・オフィス

すばる望遠鏡

Organization



NAOJ Facilities

NAOJ Okayama

■Okayama Astrophysical Observatory

NAOJ Nobeyama

■Nobeyama Radio Observatory

NAOJ Mizusawa

■Mizusawa VLBI Observatory (VERA)

Seven VLBI Stations (including Four VERA Stations)

■Mizusawa VLBI Observatory : Yamaguchi Station

■Mizusawa VLBI Observatory : Iriki Station (VERA)

■Mizusawa VLBI Observatory : Kagoshima Station

■Mizusawa VLBI Observatory : Ishigaki-jima Station (VERA)

■MURIKABUSHI
is a 105-cm telescope in Ishigaki-jima Astronomical Observatory.

■Mizusawa VLBI Observatory : Ogasawara Station (VERA)

NAOJ Mitaka

NAOJ Chile

■NAOJ Chile Observatory
ALMA

NAOJ Hawai'i

■Subaru Telescope (in Hawai'i)

Hilo Office

Subaru Telescope

■Mizusawa VLBI Observatory : Ibaraki Station

Takahagi, Hitachi,
Ibaraki Prefecture

外部評価当日のスケジュール

平成 27 年

2/23 (月)	16：00　天文台談話会（Tony Tyson 先生講演）	
2/24 (火) 1 日目 ・天文台全体 ・基幹 ALMA ・A. 電波 ・C.ATC, 情報 C	9：00　Welcome Speech（林台長）、評価委員 13 名の紹介（渡部委員長） 9：30　天文台全体と各研究部・プロジェクト・センターの概要紹介（30 分） 10：00　発表 + ヒアリング **【天文台全体：執行部】**（1 時間） 11：00　発表 + ヒアリング **【基幹プロジェクト：ALMA】**（1.5 時間）	Room1
	12：30　昼食	
	13：30　発表 + ヒアリング **【グループ A：水沢→野辺山→ RISE】**（1 時間 40 分）	Room1
	（10 分間 休憩）	
	15：20　発表 + ヒアリング **【グループ C：ATC →情報 C】**（1 時間）	Room1
	（10 分間 休憩）	
	16：30　◎本日のレビューまとめ（1 時間）	Room2
	17：30　（休憩 + 準備）	
	18：00　Welcome Party（評価委員、執行部、プロ長、準備委員） 20：00　（解散：ホテルへ移動）	Room1
2/25 (水) 2 日目 ・基幹 Subaru ・基幹 TMT ・B. 光赤外 ・C. ADC	9：00　発表 + ヒアリング **【基幹プロジェクト：Subaru 】**（1.5 時間）	Room1
	（10 分間 休憩）	
	10：40　発表 + ヒアリング **【基幹プロジェクト：TMT】**（1.5 時間）	Room1
	12：10　昼食	
	13：10　発表 + ヒアリング **【グループ B：JASMINE →岡山→系外惑星→重力波】**（2 時間）	Room1
	（10 分間 休憩）	
	15：20　発表 + ヒアリング **【グループ C：ADC】**（30 分）	Room1
	（10 分間 休憩）	
	16：00　◎本日のレビューまとめ（2 時間）	Room2
	18：00　（ホテルへ移動）	
	19：00　Meeting Dinner（評価委員、執行部）@ ホテル（新宿）	
2/26 (木) 3 日目 ・D. 太陽 ・E. 理論 /CfCA ・若手ヒアリング	9：00　発表 + ヒアリング **【グループ D：ひので→ SOLAR-C →太陽電波→太陽観測所】**(2 時間）	Room1
	（10 分間 休憩）	
	11：10　発表 + ヒアリング **【グループ E：理論→ CfCA】**（1 時間）	Room1
	12：10　昼食	
	13：10　若手研究者ヒアリング（1 時間 20 分） 14：30　Q&A タイム	Room3
	（10 分間 休憩）	
	15：30　◎レビュー全体のまとめ（評価委員 + 準備委員のみ）（2.5 時間） 18：00　Closing Speech（林台長）	Room2
	18：30　（解散：ホテルへ移動）	
2/27 (金)	各研究部・プロジェクトごとに、関連分野の評価委員の先生と打合せ・セミナー。 16：00　天文台談話会（Jocelyn Bell 先生講演）	

*Room1：大セミナー室、Room2：院生セミナー室、Room3：講義室

Schedule of NAOJ External Review

2015

Feb. 23 (Mon)	16：00	NAOJ colloquium（Lecture by Prof. Tyson）	
Feb. 24 (Tue) Day 1 ・NAOJ ・Core (ALMA) ・A. Radio ・C. Advanced Tech C and Public Relations C	9：00 9：30 10：00 11：00	Welcome Speech by Director General and Introduction of the Review Panel members by Vice Director General. (30 minutes) Brief introduction about general outline of NAOJ and Division/Projects/Centers. (30 minutes) Presentation & Q/A **【NAOJ】** (1 hour) Presentation & Q/A **【Core Project：ALMA】** (1.5 hours)	Room1
	12：30	Lunch	
	13：30	Presentation & Q/A **【Group A：Mizusawa → NRO → RISE】** (1 hour and 40 minutes)	Room1
		(10 minute break)	
	15：20	Presentation & Q/A **【Group C：ATC → PRC】** (1hour)	Room1
		(10 minute break)	
	16：30	◎ Summary of Today' s Review (1 hour)	Room2
	17：30	(Break and Preparation)	
	18：00 20：00	Welcome Party（Review Panel members, NAOJ Directorate, Project Managers, Preparatory Committee members） （close：move to the Hotel）	Room1
Feb. 25 (Wed) Day 2 ・Core (Subaru) ・Core (TMT) ・B. Optical & Infrared ・C. Astron Data C	9：00	Presentation & Q/A **【Core Project：Subaru Telescope】**（1.5 hours）	Room1
		(10 minute break)	
	10：40	Presentation & Q/A **【Core Project：TMT-J】**（1.5 hours）	Room1
	12：10	Lunch	
	13：10	Presentation & Q/A **【Group B：JASMINE → Okayama → ExtraSolar → Grav.Wave】**（2 hours）	Room1
		(10 minute break)	
	15：20	Presentation & Q/A **【Group C：ADC】**（30 minutes）	Room1
		(10 minute break)	
	16：00	◎ Summary of Today' s Review（2 hours）	Room2
	18：00	（move to the Hotel）	
	19：00	Meeting Dinner（Review Panel members, NAOJ Directorate） at KEIO Plaza Hotel in Shinjuku	
Feb. 26 (Thu) Day 3 ・D. Solar ・E. Theoretical Astronomy	9：00	Presentation & Q/A **【Group D：Hinode → SOLAR-C → Solar Radio → Solar Obs】**（2 hours）	Room1
		(10 minute break)	
	11：10	Presentation & Q/A **【Group E：Theoretical Astronomy → CfCA】** （1 hour）	Room1
	12：10	Lunch	
	13：10 14：30	Hearing from the young researchers（1 hour and 20minutes） Q&A Session	Room3
		(10 minute break)	
	15：30 18：00	◎ Summary of Complete Review（Review Panel members and Preparatory Committee members only）(2.5 hours) Closing Speech（by Director General Hayashi）	Room2
	18：30	（close：move to the Hotel）	
Feb. 27 (Fri)	Each Project holds an internal seminar/meeting with a reviewer in their field. 16：00 NAOJ colloquium（Lecture by Prof. Jocelyn Bell Burnell）		

* Room1：Large Seminar Room, Room2：Graduate Students Seminar Room, Room3：Lecture Room

若手研究者ヒアリング参加者名簿
Hearing from the NAOJ Young Researchers

Date ：February 26 (Thursday), 2015
Time：13:10~14:30
Place：Lecture Room
Participants from NAOJ:

Core: Subaru	松岡　良樹 MATSUOKA, Yoshiki	光赤外研究部 / 特任助教 Division of Optical and Infrared Astronomy/ Specially Appointed Assistant Professor
Core: ALMA	HERRERA, Cinthya （シンシア　エレラ）	チリ観測所 / 特任研究員（プロジェクト研究員） NAOJ Chile Observatory/ Specially Appointed Research Staff （Project Research Fellow）
Core: TMT-Japan	橋本　哲也 HASHIMOTO, Tetsuya	TMT 推進室 / 研究員 TMT-Japan/ Ph.D Research Fellow
Group A: Radio	秦　和弘 HADA, Kazuhiro	水沢 VLBI 観測所 /JSPS 特別研究員 Mizusawa VLBI Observatory/ JSPS Postdoctoral Fellow
Group B: Optical & Infrared	Peña ARELLANO, Fabián Erasmo （ペーニャ　アレリャーノ ファビアン　エラスモ）	重力波プロジェクト推進室 / 特任研究員（プロジェクト研究員） Gravitational Wave Project Ofiice/ Specially Appointed Research Staff （Project Research Fellow）
Group C: Centers	小嶋　崇文 KOJIMA, Takafumi	先端技術センター / 助教（ALMA 開発担当） Advanced Technology Center/ Assistant Professor
Group D: Solar	鳥海　森 TORIUMI, Shin	太陽天体プラズマ研究部 / 特任助教（国立天文台フェロー） Division of Solar and Plasma Astrophysics/ Specially Appointed Assistant Professor （NAOJ Fellow）
Group E: Theory	平居 悠 HIRAI, Yutaka	理論研究部 / 東京大学大学院天文学専攻 M2 Division of Theoretical Astronomy/ Graduate Student (M2), Department of Astronomy, The University of Tokyo

NAOJ External Review Committee Report 2015

21 August, 2015

Contents

1 EXECUTIVE SUMMARY

The most significant development of the last five years must be the growing and highly successful Japanese participation in major international astronomical projects. This is good for astronomy worldwide and we believe good for Japan also. That Japan is now playing an international leadership role (e.g. in TMT) is an excellent development. The review panel wishes to congratulate NAOJ on its successes in these areas, highlighting especially its three core projects ALMA, Subaru and TMT. Alongside this we acknowledge and welcome the growing links with other East Asian countries; again this is good for astronomy worldwide.

We judge it important that Japan continues to secure its international profile and provides appropriate leadership in the worldwide astronomical community. To this end its highest priorities should be its international projects. To achieve this NAOJ should be clear which projects only it can accomplish, and which could be accomplished elsewhere in Japan or East Asia. NAOJ already has good relationships with Japanese Universities and East Asian institutes which should be built upon. However we hope also that NAOJ can continue sufficient small projects (perhaps in collaboration with universities) that there is opportunity for creativity, innovation and experimentation with new techniques. We recognise that funding and staff resources are finite; therefore, relative prioritization will be required in the years ahead and we comment on that in the individual sections. We also recommend that heads of units should be made aware of the full staff costs of their unit, even if they do not have control over all those resources.

NAOJ has also provided leadership in astronomical research in Japan and helped train many graduate students and young researchers in science and engineering who have gone on to faculty positions within NAOJ and in the universities. As in many major observatories in many countries there is a tension here between the service role of an observatory and the need to retain top class staff who are also stimulated by research and the training of young astronomers. There is no simple solution here but it is essential that staff remain in contact with research; we recommend that funding to hire post-docs be protected. It is good that there is a strong Department of Theoretical Astrophysics (DTA) within the Observatory.

It is now widely recognised in Europe and the Americas that a diverse group (be it a research group or a business) is more successful than a less diverse group, with better robustness and flexibility. The Review Committee welcomes the recent appointment of a female member of the scientific staff and encourages the Observatory to take advantage of the current opportunity to advertise women-only positions to recruit some more excellent female scientists. We also recommend that in future disaggregated staff numbers are recorded (i.e. the male and female numbers are reported separately). We further recommend that NAOJ strengthens the international/cultural diversity of its staff. This will become increasingly important in the era of very large international projects such as TMT. We note that the leadership of the East Asian Institutes have English as their working language, and judge that increasing internationalization of the staff will lead to increased use of English in the Observatory.

2 INTRODUCTION

The NAOJ External Review Committee met at NAOJ Tokyo on February 24, 25 and 26, 2015. The Review Committee membership is given in the Appendix. In advance of the meeting the Review Committee was given overview material and extensive documentation on each project. While at NAOJ we received presentations introducing NAOJ and presentations summarising the major points for each project and had opportunity to ask questions; those presentations were subsequently made available to us. We had confidential meetings with Director General Hayashi, a meeting with young researchers, and an opportunity to see some of the facilities on site.

3 NAOJ ' s CHARGES TO THE PANEL

Our brief was as follows;
'We would like to ask the panel to review the activities of NAOJ in the past five years, primarily referring to our missions and expected products.

The specific items we would like to ask the panel to review are the followings:

1. Which of the NAOJ Projects, if any, and what kind of their activities are at the world-leading level? Please identify the Projects and specify their activities that are evaluated at the world-leading level.
2. Are the NAOJ Projects or researchers producing outstanding science outcomes? Please evaluate both the NAOJ Projects (including the outcomes produced by open-use users of NAOJ facilities) and the achievements by the NAOJ project members themselves.
3. What are the strong and weak points of NAOJ (specific to the top administration, each Project or Center, etc.) in terms of their governance, management, structure, and use of resources?
4. What are the issues that NAOJ (specific to the top administration, each Project or Center, etc.) needs to improve?'

4 REPORT ON CORE PROJECTS

4.1 ALMA

Overall Evaluation - world-leading and with excellent early science
Area needing further attention - staff safety/security

The External Review Committee finds that the performance of NAOJ in the ALMA project is world leading.

- NAOJ (via NINS) joined the ALMA collaboration in 2004, two years after the NRAO (via NSF) and ESO signed their Bilateral Construction Agreement. However, NAOJ was first to deliver an ALMA 12m antenna (2008), first to deliver all of their antennas which compose the ACA (2013), first to deliver all of their 17 Front End systems (FEs) (2012) and then 9 more for NRAO and ESO. NAOJ also delivered all of their 219 receiver cartridges (B4, B8, B10) ahead of schedule (2013), as well as the ACA correlator system.

- NAOJ contributed components which all performed better than the original specifications in terms of surface accuracy (antennas), and system temperatures (receivers).
- NAOJ has developed key technologies, as evidenced by the 16 patents earned via the ALMA project, and also the superconducting junction fabrication facilities within the NAOJ Advanced Technology Center (ATC). They are also leading developments for the next Band 1 receivers and the Band 11 receivers.
- NAOJ established the NAOJ Chile Observatory, deploying 23 staff members to Chile (12 serve as international members of JAO, including important management roles as Project Manager and Chief Scientist at various times). These staff have been contributing to the commissioning and science verification activities for ALMA. In particular, they have made important contributions to operations with long baselines, with polarization capabilities, at high frequencies, and for solar studies.
- NAOJ established the NAOJ/East Asia ALMA Support Center (ASC) to continue maintenance and development of ALMA components, and to support science programs within the user community.
- NAOJ forged an East Asian partnership in ALMA, with ASIAA (2005) and KASI (2012), strengthening their staff and financial resources.
- NAOJ ALMA project has a very robust program in public outreach and education activities, which is in addition to the general NAOJ outreach program. In particular, almost 300 news and press releases, almost 200 public talks, and a strong presence on the social media, have produced high levels of awareness and interest in the public.
- NAOJ promotes science activities and collaboration throughout East Asia, with ALMA Users Meetings, ALMA Town Meetings, ALMA Workshops, ALMA International Meetings, and most recently the ALMA Postdoc Symposium. These activities promote collaborations and more competitive ALMA proposals.
- NAOJ ALMA project has produced excellent early science results, which include the primordial galaxy merger "Himiko" at z=6.6, gas in GRB host galaxies, the formation of disk galaxies, infalling gas and chemistry near the protostar L1527, and protoplanetary disks. These results from the Early Science Operations demonstrate the increased sensitivity and potentials of ALMA as well as providing a strong indication that ALMA will fulfil its promise to be " transformational ". They demonstrate that the science community in Japan is working at the frontier, and is competitive.

The NAOJ has fully addressed the concern and advice from **the last external review** in 2008. NAOJ has strengthened their staff and financial resources, by bringing in their East Asian partners in Taiwan and Korea. They have continued to grow and cultivate both the scientific and public communities in Japan. The NAOJ ALMA team has worked closely and smoothly with their international partners, in North America, in Europe, and in East Asia. The NAOJ enjoys high visibility and support by the public. Their performance has secured the operational budget for their ALMA project going forward.

Commentary and Recommendations

The outstanding performance of the NAOJ ALMA project team has demonstrated that NAOJ and the Japanese astronomical community are fully internationally competitive in astronomical research and development. As one of three core projects within NAOJ, the ALMA project team has demonstrated leadership in technical expertise, in delivery of subsystems on time, on budget, and on specification, in integrating and calibrating the entire ALMA system, and in working smoothly with industries in Japan. The NAOJ is now clearly

a very reliable partner and a clear leader in global astronomical efforts.

NAOJ continues to be heavily invested in the ALMA project in the future. Both technical and personnel requirements remain high for operations, maintenance, and future development. Integrating the East Asian efforts will be important, as well as future expansion of this partnership to other countries in the region. The pursuit of, and the publication of ALMA science results, will require increased efforts and increased investments.

Recommendation 4.1.1: NAOJ continues its major, highly successful role in ALMA, putting in further resources if required; the involvement of other countries in the region should be increased.

Recommendation 4.1.2: Although significant effort has already been made, effort to further improve the safety/security of staff at NAOJ Chile Observatory should be continued and enhanced in the future.

4.2 Subaru

Overall Evaluation - excellent with outstanding science in several areas
Area needing further attention - staff safety/security, and preventative maintenance and upgrades.

The External Review Committee finds that the performance of NAOJ in the Subaru project is excellent.

- By all international standards, Subaru has been and continues to be a very successful facility.
- Hyper-Suprime-Cam (HSC), Prime Focus Spectrograph (PFS), and their associated key projects will provide world-best capabilities and datasets until at least 2020. ULTIMATE-Subaru is a very attractive option for the future.
- The Subaru Strategic Programs (SSPs) create new opportunities to exploit these technological strengths effectively.
- Engagement with the East Asian scientific community as well as other international observatories on Mauna Kea seems timely and effective, as does the Subaru public outreach in Hawaii.
- Over all, Subaru will remain critical for Japanese international leadership in ground-based optical-infrared astronomy even with the arrival of the Thirty Meter Telescope (TMT).
- In the 8-m class facilities, Subaru continues to play a dominant role because of its wide-field capabilities.

The stated objectives and plans for instrumentation are appropriately forward-looking. Financial support for ULTIMATE-Subaru should be vigorously pursued.

Commentary and Recommendations

To ensure continued success, the committee suggests a number of action items.

Streamlining the Suite of Instruments. The balance between targeted high impact science such as HSC surveys and the availability of a large suite of instruments depends on the proposal pressure from the users' community. The nature of HSC and PFS science, which requires large investments of telescope time, will necessarily make it more difficult to have a

large number of instruments deployed on the telescope. The committee therefore supports the Subaru effort to decommission and replace older facility instruments. The committee also supports the Subaru effort to move some instruments and science to other available telescopes. Reducing the number of instrument changes per year will also minimize overall unscheduled technical downtime. Operating higher impact instruments for more nights, combined with more survey observing (complementing larger imaging surveys in the 2020s), will increase Subaru's impact relative to other facilities.

Engaging University Groups and Support to the Community. The NAOJ and the Subaru project have the tradition of working with university groups in producing instruments for Subaru. This has been important for the training of the future generation, and for keeping university groups engaged and supporting the national facilities. A healthy and strong university community will be important for the future of Japanese astronomy. The number of PI-type instruments should be selected with care in consultation with the community. The science and technology benefits of supporting PI-type instruments need to be weighed against the costs of instrument changes, demands on Subaru staff to help support non-standard instruments, and night-time taken away from other programs (e.g., Subaru Strategic Programs). The committee recognizes that the collaboration with the university community is a strong attribute of Subaru, and should be pushed continuously.

Recommendation 4.2.1: The program to decommission older instruments, reduce the number of instrument changes, operate more with higher impact instruments and with more survey mode observations should be pursued. PI-type instruments should be selected with care.

Engaging the East Asian and International Community. The NAOJ and Subaru project has been engaging the East Asian community in order to enlarge its users' community. This is seen to be important for building support for future operations and instrumentation for Subaru, as well as for the TMT. Subaru also exchanges time with other Mauna Kea facilities. This will encourage better coordination and utilization of all the facilities, and also provide the Japanese community with access to other facilities. The committee recognizes and lauds these efforts and endorses their continuation.

Recommendation 4.2.2: The program to enlarge the East Asian user community should continue. Exchanges of time with other Mauna Kea telescopes should continue.

Preventive Maintenance and Upgrades. Because of the high scientific impact of Subaru and the large recent investments in HSC and PFS, improving telescope efficiency in terms of minimum technical downtime would have high value. The committee recommends targeted preventive maintenance and continual upgrades of sub-systems as excellent investments with high return. The committee recommends continual allocation of well experienced personnel as well as sufficient budget and effort in this area.

Strengthen safety/risk mitigation. Regular internal staff meeting(s) and improved communications have already been implemented. The committee recommends a full-time safety/risk management officer to operate directly as part of the Subaru Director's office. Consultation with and utilization of external safety advisors may be very useful.

Recommendation 4.2.3: We urge more resources in terms of budget and staff resources for (a) safety/risk management; and (b) overall facility preventive maintenance and upgrades.

4.3 Thirty Meter Telescope (TMT)

Overall evaluation - world leading
Area needing further attention - strengthening and extending the organization of TMT-J.

The External Review Committee finds the performance of NAOJ in the TMT project to be world leading.

- Overall, the TMT-J activity is in excellent shape. However, funding challenges exist both internally and at the NINS (and above) governmental level. Neither of these funding challenges is completely under NAOJ control, adding understandable but also unavoidable risk to the TMT-J activity.
- Since joining the project in 2008, NAOJ has emerged as a strong scientific, technical, and financial leader within the Thirty Meter Telescope (TMT) project, now officially the TMT International Observatory (TIO). Indeed, by the end of construction in 2024, NAOJ will have made equivalent or greater contributions in all areas than any other partner, making it the largest partner. Coming after previous successes with Subaru and ALMA, TMT-J is already another significant international success for the NAOJ program as well as a major opportunity to further Japanese leadership in astronomy and astrophysics on a global scale.
- While there are activities within NAOJ that might be accomplished elsewhere within the Japanese university community, NAOJ appears to be the only astronomical organization within Japan capable of representing Japan in this major international project and working with Japanese industrial partners to deliver major TMT components. In order to keep up with rapidly increasing TMT activities, the organization of TMT-J should be extended and strengthened. As NAOJ faces hard financial decision in the years ahead, it is imperative to keep the TMT-J group strong to maintain and extend Japanese leadership within TMT.
- Technology development for TMT, especially in focal plane instrumentation, creates a significant opportunity for collaboration between NAOJ, Japanese universities, and other institutions throughout East Asia. The development of such collaborations has already begun and should be continued with high priority.
- Science leadership within the TMT International Science Development Teams (ISDTs) by Japanese scientists from NAOJ and various Japanese universities is highly significant. Such international leadership grows from the earlier investments in Subaru and ALMA as well as close scientific ties between NAOJ and the Japanese university community. Such intra-Japanese collaboration will remain critical in the years ahead.

Response to the Recommendations of the Last External Review

All specific activities (internal research by the group, collaboration with other Japanese groups, education and public outreach, and the acquisition of external funding) have been very successful since **the last external review**. There were five items recommended in the 2008 Review: (1) to establish the Japanese contributions to TMT; (2) to explore and select which instruments should be constructed in Japan; (3) to build community support; (4) to establish a formal partnership and; (5) to prepare the budget request. All five items were successfully completed.

Commentary and Recommendations

The five-year plan as presented is appropriately ambitious to enforce Japanese leadership. However, if the overall TIO partnership evolves, opportunities may arise for further Japanese involvement in development and construction activities.

Recommendation 4.3.1: NAOJ is encouraged to watch for opportunities for further Japanese involvement and seize them whenever possible.

Given the emergent role of NAOJ within the TMT International Observatory (TIO) on behalf of the Japanese community and other East Asian partners, NAOJ is encouraged to take a more active role in TIO governance and high-level policy development. TMT is not a Californian project with Japanese participation; rather, TMT is an international collaboration with Japan as its most significant partner. In particular, NAOJ should actively ensure that TMT is operated in a way that is consistent with Japanese organization, culture and aspirations. However, since TMT operations will ultimately involve international use of all instruments, we recommend developing close collaborations with all stakeholders.

Recommendation 4.3.2: NAOJ is encouraged to take a more active role in TIO governance and high-level policy development. Close collaborations with all stakeholders should be developed.

The organization structure of TMT-J is rather complex. In some cases, the same person shares multiple roles within TMT-J as well as between TMT-J and other NAOJ activities. This should be reviewed and whenever possible each person should focus on as few activities as possible. Some groups within TMT-J appear to be too small to carry out their roles. Hiring experienced personnel will be required.

Recommendation 4.3.3: The organization of TMT-J should be reviewed as a priority and simplified where possible; it will need extending and strengthening as the project grows.

An intellectual atmosphere will be compromised unless there is innovation. Core projects such as TMT need to be managed carefully so as not to consume all the resources necessary for the small projects that are innovators and incubators. To broaden the research and staffing base, some small projects could be conducted jointly with universities.

5 REPORT ON GROUP A PROJECTS

5.1 Mizusawa VLBI Observatory

Overall evaluation - good
Area needing further attention - The future of Mizusawa VLBI observatory after the VERA should be planned.

The External Review Committee finds the performance of NAOJ in the Mizusawa VLBI Observatory project to be good.

- The Mizusawa observatory has kept stable operation of the VLBI Exploration of Radio Astrometry (VERA) providing about 4000 hours/year observing time and increasing the number of the astrometry measurements steadily. Open-use observations of VERA have been conducted successfully.

- The Mizusawa observatory has participated in almost all Japanese VLBI Network (JVN) observations.
- The Mizusawa observatory constructed the combined VLBI array with the Korean VLBI Network (KaVA) and started open-use from February 2014.
- The Mizusawa observatory has started VLBI test observations for the East Asian VLBI Network (EAVN) and fringes were successfully detected.
- The Mizusawa observatory has contributed to the education of PhD students in radio astronomy; 11 people obtained PhDs based on VERA and JVN research during 2010-2014.
- The Mizusawa observatory has been keeping the Japan Standard Time.

The NAOJ Mizusawa team has addressed the concern and advice from **the last external review** in 2008. The pipelines for data analysis were developed and the number of publications was significantly improved. It is remarkable that some of the publications have had high impact on their research field (e.g., Honma et al. 2012). Significant improvement in international collaboration has been achieved. The construction of KaVA and the start of open-use observations are especially noteworthy. EAVN is also an important project for international collaboration. The operation of VERA and other networks with universities is a new style for NAOJ, one that is successful in supporting research and education carried out at universities. Keeping Japan Standard Time during the power outage period just after the huge earthquake in March 2011 is laudable.

Commentary and Recommendations

International collaborations such as KaVA and EAVN are important for the development not only of instruments but also of human resources in East Asia and should be encouraged. The potential for more international collaboration should be explored but balanced against other NAOJ commitments. Since EAVN is operated with Korea and China which are members of the East Asian Observatory (EAO), it is worth thinking about future operation of EAVN by EAO. However, since the future of Mizusawa VLBI observatory after the VERA is not clear, the plan for the observatory has to be developed.

Recommendation 5.1.1: A plan for the Mizusawa observatory has to be developed.

5.2 Nobeyama Radio Observatory (NRO)

Overall evaluation - good
Area needing further attention - decommissioning of old instruments, solutions to the remaining single point failures, and the future role of the 45-m telescope.

The External Review Committee finds the performance of NAOJ in the NRO project to be good.

- NRO provides more than 4000 hours/year observing time on the 45-m telescope for open-use and internal observations including the Legacy Projects. More than 30 papers have been published in refereed journal annually in the last 5 years.
- NRO has developed a new observing system which includes the 2-beam dual sideband (2SB) receiver and new digital backend. The new multi-beam receiver FOREST is also being developed.
- NRO has implemented a remote observation capability of the 45-m telescope, along with switching to Linux.

- NRO has completed refurbishments of some critical parts of the 45-m telescope following the NRO antenna master plan.
- NRO is developing the ASTE TES Bolometer camera.
- NRO conducts various programs to educate students in mm-wave and radio astronomy.

The NAOJ NRO team has addressed the concern and advice from **the last external review** in 2008. NRO developed the new observing system including the new digital backend which can take over from the old AOS. NRO is also upgrading the multi-beam receiver using 2SB SIS mixers. The 45-m telescope with the wide band digital backend and the new multi-beam receiver FOREST will be still competitive in mapping at 3-4 mm. NRO is playing an essential role in nurturing the next generation for the ALMA era. The committee highly appreciates the efforts made by NRO to carry out activities with very limited staff resources. NRO is also an important hub for public outreach by NAOJ. It is remarkable that there are about 60,000 visitors every year.

Commentary and Recommendations

The committee recommends completion of the solutions to the remaining single point failures as soon as possible, before they cause serious loss of observing time. The completion of the development of FOREST should be the first priority among the NRO development items. To overcome the problem of shortage of staff resources, collaboration with universities should be encouraged. Including universities in a Legacy Project is a good way to make a big science impact and educate the younger generation using the 45-m telescope. Collaboration on the development of instruments with universities is also important, giving their graduate students the chance to learn radio astronomy using the world-class telescope. To reduce the burden on NRO staff, the committee endorses the plan to decommission old instruments which can be replaced by new ones.

Recommendation 5.2.1: Old instruments should be decommissioned as planned to reduce the burden on NRO staff, and solving the remaining potential single point failures should be given high priority.

Recommendation 5.2.2: Consideration has to be given to the role that the 45-m telescope should play in the ALMA era.

5.3 RISE (Research of Internal Structure and Evolution of Solar System Bodies)

Overall evaluation - good
Area needing further attention - The data from KAGUYA and Hayabusa 2 should continue to be exploited.

The External Review Committee finds the performance of NAOJ in the RISE project to be good in adverse circumstances

- The NAOJ RISE project was previously focused on the KAGUYA (SELENE) mission. This Lunar Orbiter project's (2007-2009) geodetic survey data are now released, and many science papers have been published.
- The RISE team developed the VLBI, the large cube mirror for the Lunar Laser Ranging experiment (LLR), and the geodetic telescope for the In situ Lunar Orientation

Measurement (ILOM) for the SELENE 2 Lunar Lander mission. Bread Board Models (BBMs) were developed, but SELENE 2 was terminated in March 2015.
- The RISE team worked on the laser altimeter (LIDAR) for Hayabusa 2 Asteroid Explorer mission launched in December 2014. Papers are being prepared for the LIDAR system.
- The RISE team is exploring participation in future projects such as the Jupiter Icy Moons Explorer (JUICE) and the Mars Exploration with a Lander-Orbiter Synergy (MELOS).
- The RISE team is teaching and working with graduate students at various universities.

The NAOJ RISE team has addressed the concern and advice from **the last external review** in 2008, by developing various survey data products for KAGUYA. The RISE team has been developing instrumentation for the SELENE 2 mission. This Lunar Lander mission has been terminated, but the developments might be useful for the MELOS mission. The RISE team has also worked on the Hayabusa 2 mission, and their data analysis going forward should be very useful. The RISE team has a good track record for publishing, and a good track record for developing components for space missions. This is an asset for NAOJ.

Commentary and Recommendations

The RISE team will continue to have data from the KAGUYA and Hayabusa 2 missions. They should continue to push their scientific publications. Their track record on working with JAXA missions should be continually pushed for future missions. They should clearly continue to work with the various universities.

Recommendation 5.3.1: The data from KAGUYA and Hayabusa 2 should continue to be exploited.

6 REPORT ON GROUP B PROJECTS

6.1 Jasmine

Overall evaluation - good
Area needing further attention - NAOJ-based data processing, and adaptation to the small-Jasmine project to enable it to reach fainter magnitudes

The External Review Committee finds the performance of NAOJ in the Jasmine project to be good.

- The Jasmine project represents the only space-astrometry project outside Europe. By observing in an infrared passband, it is able to cover a range of sources that is beyond the reach of the Gaia satellite due to severe reddening. This will allow for the first time the measurement of parallaxes in areas that at visual wavelengths are largely obscured by interstellar dust.
- The Jasmine project is split into three satellite missions, the first of which, nano-Jasmine, has been ready for launch for about 4 years. Launch delays were outside the control of the Jasmine team. Nano-Jasmine is to be seen as an experiment for techniques to be deployed in the “small-Jasmine”, and possibly later in “medium-Jasmine”. The “small-Jasmine” mission has been designed such as to fit within an ISAS/JAXA small satellite mission proposal.

- While nano-Jasmine is a two-aperture instrument for measuring absolute parallaxes, using the same principles as Hipparcos and Gaia, small-Jasmine and medium-Jasmine are single aperture missions. They can only measure differential parallaxes, which require calibration to obtain absolute values. It is, however, likely that a reference frame of suitable accuracy for this calibration can be obtained from the Gaia data.
- Nano-Jasmine is ready for launch; there are clear plans for small-Jasmine, and plans and alternatives (VERA) for medium Jasmine. The feasibility of medium-Jasmine is not clear at this stage, but remains the ultimate goal.

Response to the Recommendations of the Last External Review

On technical aspects there has been an excellent response, but on the scientific aims and possibilities there are still some questions left. Although in the original Jasmine design the astrophysical impact was expected to be very significant, this is no longer clear in small Jasmine, with its reduced aperture size. An assessment of the expected performance of small Jasmine for observing towards the Galactic Centre, compared with the expected performance of Gaia for the same region, should clarify this.

Commentary and Recommendations

The data processing for nano-Jasmine is foreseen as a collaboration with the Gaia data processing centre at European Space Astronomy Center (ESAC). Considering that it now seems that launch is delayed till 2017, we recommend that the Jasmine team invests in building up more knowledge of the nano-Jasmine data processing through detailed simulations and experiments, in order to ultimately being able to do the processing of the nano-Jasmine data in its entirety at NAOJ. This requires more experienced regular support on developing data simulation and processing activities, but will create a much improved understanding of the astrometric data produced by the mission.

Recommendation: 6.1.1 The Jasmine team develops a more thorough understanding of the data processing, with the goal of the processing being done at NAOJ.

In order to fit the small-Jasmine mission within the ISAS/JAXA small-mission concept, the telescope aperture has been decreased to 30 cm. This impacts on the limiting magnitude, and from the presentations it has not been clear whether under these conditions the original scientific aims of the mission, such as reaching deeper than the Gaia mission in obscured regions towards the galactic centre, are still met.

Recommendation: 6.1.2 We recommend adaptations are made to the small-Jasmine project such that it can reach to fainter magnitudes. Depending on the current mission limitations, these adaptations could be to the spacecraft and payload design, the detectors and electronics, or even the data collection and analysis.

The planned international collaboration between small-Jasmine and the SDSS-IV/APOGEE-2 project is an excellent addition to maximise the scientific impact of small-Jasmine.

6.2 Okayama Astrophysical Observatory (OAO)

Overall evaluation - good
Area needing further attention - the future plan for OAO

The External Review Committee finds the performance of NAOJ in the Okayama Astro-

physical Observatory project to be good.

- The main telescope of Okayama Astrophysical Observatory (OAO) is the 1.88-m (74-inch) telescope, which has been operated since 1960. Open use of the 1.88-m telescope is smoothly carried out with very limited staff resources, with a moderate oversubscription rate.
- The current scientific activity of OAO is not low but limited, since the telescope apertures are relatively small.
- The average number of papers published per year based on OAO data is low.
- Efficient use of the 1.88-m telescope with an optimized instrument (e.g. the High Dispersion Echelle Spectrograph, HIDES) has been achieved.
- OAO has developed astronomy research activities in some areas together with observatories in East Asia and others.

Response to the Recommendations of the Last External Review

The last external review committee recommended a simpler, more focused operating model for OAO to retain much of the scientific productivity with fewer staff and capital resources. We confirmed that OAO has made significant efforts to meet the recommendation, focusing on, for example, Doppler measurements of extra-solar planet systems with HIDES.

The previous committee expressed concern about the range of motivations the different stakeholders have for building the 3.8m telescope, and suggested that NAOJ and Kyoto University needed to agree to explicit performance requirements, a project schedule and the division of the operating costs so that the project team can focus on specific goals. We found that the project schedule has now a clear target year (2018) and that Kyoto University is the central institute to build the telescope, but operating cost discussions are not completed yet.

Commentary and Recommendations

It is very important for NAOJ to mentor the next generation of world leading researchers, and local telescopes should play important roles for innovative activities and new ideas. NAOJ, as an intra-university institute, should take a key role to integrate activities not only by Japanese large universities but also by other universities.

Although open use of the 1.88-m telescope is carried out well, not many graduate students are involved, partly because the telescope aperture is not very large, and also because the instrument has been rather focused on relatively few science programs. OAO is involved in the Optical and Infrared Interuniversity Cooperation Program, but the outcome is not significant. The 91-cm telescope is not yet used for a NIR wide-field survey. These issues should be improved together with the future plan of the observatory.

When we consider that "back-yard" optical-infrared telescopes inside Japan are very limited, OAO could be extended and be operated possibly by Kyoto University together with a new 3.8-m aperture telescope, which could be the central telescope for Japanese intra-university domestic telescopes. This may require reducing or terminating other OAO activities.

As significant time on the 3.8-m telescope is going to be open to the Japanese community, it is natural that NAOJ will support a part of the operation of the observatory. However, the unusually complex design (relative to other 4-m class telescopes built in the last 10 years) of the new 3.8-m telescope may lead to high annual operations costs. Careful consideration

is required to find the balance between the back yard activities at OAO and the frontier activities elsewhere within the NAOJ program.

Recommendation 6.2.1: An overall operations, maintenance, and development plan for OAO should be developed. In particular, the 3.8-m operations phase agreement with Kyoto University should be worked out.

6.3 Extrasolar Planets

Overall evaluation - world leading with outstanding science in IR imaging of extrasolar planets and imaging of circumstellar disks
Area needing further attention - an increase in FTE level

The External Review Committee finds the performance of NAOJ in the Extrasolar Planets project to be world leading.

- The Extrasolar Planet Project Office (ESPO) has been highly successful over the reporting period, with new techniques being developed and applied, and a wide range of exciting results. The output of this relatively small group of researchers is very high in both professional refereed papers and outreach.
- The IR imaging of extrasolar planets is particularly impressive, as is the imaging of features in circumstellar disks. These results well-justify the large award of Subaru time to the Strategic Exploration of Exoplanets and Disks with Subaru (SEEDS) project.
- Plans for future developments are well thought through, realistic, and promise further exciting results. There are clear, well defined instrumental development plans that promise further exciting data - the Infrared Doppler Instrument (IRD) for Subaru, the Second Earth Imager for TMT (SEIT), and WFIRST AFTA COronagraph (WACO).
- While this group is facing increased international competition in the area of high-contrast imaging from the (e.g.) Gemini/GPI and VLT/SPHERE groups, the ESPO group has built a strong foundation for continued international leadership, especially if they can bring their TMT and WFIRST plans to fruition.

Recommendation 6.3.1: We recommend an increase in FTE level for the scientific interpretation of the data and continuation of the developments and exploitation of the IR imaging techniques as planned.

6.4 Gravitational Waves (KAGRA)

Overall evaluation - good
Area needing further attention - contribution to the GW network

The External Review Committee finds the performance of KAGRA project to be good.

Progress since the last external review

The last NAOJ External Review Committee recommended "The GW (Gravitational Wave) group stands at a crossroads. To remain at the forefront they should either pursue LCGT or engage formally in one of the other next generation detectors."
Since 2009 the Gravitational Wave Project Office at NAOJ along with colleagues at ICCR (U Tokyo) and KEK have:

- Got approval and funding for the LCGT, now known as KAGRA
- Excavated the tunnels and caverns
- Almost completed the infrastructure
- Started the detector installation
- Planned initial observations starting at the end of 2015 (although still without the full sensitivity)
- Exploited the existing MOU with LIGO for full sharing of data and joint data analysis; helped with LIGO science runs and data analysis.
- Technical collaboration is also foreseen, as is another MOU with VIRGO

Commentary and Recommendations

Gravitational waves allow us to view the universe from a new perspective and are expected to give unique astrophysical insights. Pulsars in binary systems have provided precision (part per thousand) measurement of gravitational waves at the level predicted by Einstein. However reliable detection by an array of Earth-based detectors of the GW waveform from in-spiraling compact objects will enable a test of gravitation in the strong field limit. The next five years will be crucial for Gravitational Wave Astronomy; if at the end of that period neither the ground based interferometers (primarily Advanced LIGO, Advanced VIRGO, GEO and KAGRA) nor the Pulsar Timing Arrays have made a direct detection there will need to be a major critical review and re-evaluation of the entire international GW effort. The ultimate predicted sensitivities are that the inspiral and merger of a pair of 1.4 $M_{\odot}$ neutron stars could be detected by Advanced LIGO out to a distance of 200 Mpc (by 2019), by Advanced VIRGO out to 130 Mpc (by 2021)and by KAGRA out to 150 Mpc (by 2019). If these sensitivities are achieved KAGRA will make a substantial contribution to the field. If then 3 or more detectors are operating simultaneously at good sensitivity for several years, there will be some chance that the GW waveform from in-spiraling black holes or neutron stars can be measured and localized on the sky sufficiently for quick follow-up imaging in the optical. Such follow-up is required to understand the nature of the source and refine the distance to the event.

Recommendation 6.4.1: We recommend that over the next five years the KAGRA project (as a whole) has sufficient funds and staff so that:

(i) The strength of directly detected gravitational waves (or an astrophysically meaningful upper limit on the strength of gravitational waves) is well determined

(ii) The position of any source is localised as well as possible when combined with all other operating detectors

(iii) The contribution of the special features of KAGRA to its sensitivity - i.e. underground operation to improve the low frequency response, the cryogenic mirrors and the vibration isolation system - is understood and recognised

(iv) The contribution of KAGRA to the GW network (primarily sky location and sensitivity) is recognised and understood

We further recommend that future developments are contingent upon the direct detection of gravitational waves (via multi-detector coincidence) so that the likely number of sources and their fluxes is better established at a signal/noise ratio enabling sky accurate location which could support multi-wavelength observations to identify the nature of the sources.

Recommendation 6.4.2: Future developments are contingent upon the direct detection of gravitational waves (via multi-detector coincidence).

7 REPORT ON GROUP C PROJECTS

7.1 Advanced Technology Center (ATC)

Overall evaluation - world leading
Area needing further attention - smooth changes in the staff

The External Review Committee finds the performance of NAOJ in the ATC project to be world leading.

- The NAOJ ATC is one of the best in the world, and compares favourably to instrumentation groups at the largest institutions worldwide. Their engineering expertise covers the range from microwave radio (ALMA receivers) to optical cameras (Subaru Hyper Suprime-Cam). The successful production of the ALMA receivers and Subaru telescope's Hyper Suprime-Cam is excellent.
- The ATC facility encompasses machining for fabrication, measurement equipment, and clean rooms. A large instrument bay supports assembly of major space and ground instruments. The ATC is a center for Japanese astronomy technology development, and is widely utilized by research organizations and universities in Japan. State-of-the-art capability exists in the key areas for the new astronomy: microwave engineering, mechanical engineering, optics, space instruments, clean rooms, thin film coating, and optical-IR detectors. Of particular interest for the future is the microwave kinetic inductance detector (MKIDS) array instrumentation.
- The ATC has a very good record of building astronomy instrumentation, often in collaboration with universities and institutes in Japan and abroad. The ATC has developed and built the ALMA receivers on-schedule. These receivers have met and exceeded specification. The ATC built the HSC mechanisms, dewar, and electronics, and are working on new instruments.
- If the TMT plans solidify, the ATC will become involved in building some TMT instruments.
- Plans for space instrumentation are also exciting, particularly LiteBIRD.
- It is good that collaborations with other institutes in Japan and international collaborations are increasingly relied on. One example is the East-Asia collaboration.

Future plans for the next 5 years are necessarily ambitious. Development of TMT instruments (IRIS, WFOS), and the ALMA receivers are top priorities for the ATC future plan. The development is ambitious and ATC should try to get enough resource (personnel, budget) for it in close collaboration with the projects.

Response to the Recommendations of the Last External Review

Good progress is seen in some of the recommendation of **the last external review**. However, further progress is required for some other recommendations. It will be very effective to pair an instrument scientist with a professional project manager engineer - particularly in the large technical construction projects. We note that this has been done in the ATC radio group, but was not yet realized for the optical/infrared detector development group. Because the development of IRIS and WFOS is the most important task of ATC (and TMT-Japan) in the near future, appropriate personnel should be employed. We recommend NAOJ-ATC to continue to develop a strategy to support space projects.

Commentary and Recommendations

We understand that ATC properly gives first priority to the strategic programs and the advanced development program, and must continue to do so. However, we consider that open-use user support is also important and ATC should try to support various kinds of technology development as much as possible especially for outside of the observatory. This includes not only offering open-use of unique equipment, but also for the technical support by experienced experts. We feel that this is an important role of ATC as the center of Japanese astronomy technology development.

Recommendation 7.1.1: There is a continuing need to focus staff resources (including hiring professional engineers) on the scientifically highest ranked projects which will have the broadest impact in astronomy. This will be critically important in the next 5 years. ATC should work with NAOJ closely to make smooth changes in the staff.

Additional Comments

(1) The Review Panel is not aware (and failed to ask at the time) how new R&D projects are initiated and how stakeholders might be involved. We encourage NAOJ management to ensure that there is a transparent process and that the process is widely known in the Observatory.

(2) High priority development (strategic) programs, such as the ALMA receivers and TMT instruments, are conducted in collaboration with the ALMA and TMT projects. We understand that the development tasks are shared between ATC and the projects, but are unclear how the task share is determined. NAOJ management is encouraged to ensure that there is a mechanism to optimize the task share between ATC and projects.

7.2 Astronomy Data Center (ADC)

Overall evaluation - world leading
Area needing further attention - more collaboration with similar astrophysics efforts world-wide

The External Review Committee finds the performance of ADC project to be world leading.

- Both data volume and data complexity are growing exponentially. Data centres have many roles: organizing and storing raw data; serving those data to the world; processing data and populating catalogs and databases; and extracting science from data by providing computation on the stored databases. This last role is perhaps the most useful, but it encounters the challenge of data complexity. This is because data is increasingly multi-wavelength and high dimensional, so that correlations over the data become computationally challenging at a faster rate than computing and storage technology is improving. The firm prediction is that if data centres at observatories are to deliver useful science value, they will soon become a major activity - larger than traditional departments of observatories.
- The NAOJ ADC does much of this, and they do it very well. The international community thinks highly of ADC. Comparing the data access portal Subaru Mitaka Okayama Kiso Archive System (SMOKA) with the world standard HST's Mikulski Archive for Space Telescopes (MAST), SMOKA retrieves raw data up to 50 times faster.
- The ADC multi-data portal Japanese Virtual Observatory (JVO) with its visualization tools is also impressive. It should link to SMOKA (once their metadata structures are

stable).
- Overall ADC has good product design and management. Their plans are necessarily ambitious, with more support required.

Commentary and Recommendations

It is a testimony to the quality of the people that the ADC is able to do this with only a few people. Soon their job will become more expansive: astro data centres of the future will also serve relational databases which incorporate reduced and analysed multi-wavelength data. JVO will move to this model; it will require more R&D and more staff. With the arrival of hundreds of petabytes of data from upcoming surveys, ADC could position themselves as a data base for East Asia. ADC has anticipated this by beginning activities toward data-intensive astronomy.

Recommendation 7.2.1: We recommend that the expected growth of this area is monitored and the extra resources necessary to keep this key centre functioning are anticipated. We recommend more collaboration with other data-intensive astrophysics efforts worldwide.

7.3 Public Relations Center (PRC)

Overall evaluation - excellent
Area needing further attention - more effort at developing two-way public interaction including using social media tools

The External Review Committee finds the performance of NAOJ in the PRC project to be excellent, but efforts to interactively engage the public are highly desirable.

- The PRC has a staff of 40 (10 permanent plus 30 contractors) and a budget of 300 MYen/year plus grants. This is comparable to the biggest astronomy public relations organizations worldwide. The PRC has seven offices: General Affairs, Public Relations, Outreach, Museum Planning, Ephemeris, Publication, and Library under a director.
- Their stated goal is to publicize NAOJ findings, communicate the wonder of the universe, provide calendar/ephemeris, distribute astronomical literature and material, and host events on astronomy. They engage in multiple outreach activities ranging from hosted events to web pages, including regular star-gazing parties at Mitaka campus,"4 Day Experience Program as an Astronomer (Kimiten)", etc. The visitor's area of Mitaka Campus is open daily to the public and they have special two-day Open Campus event every year.
- By their measure (web hits) their impact is the top of Japanese science institutes and more than 8% of the University of Tokyo, the Japanese leading university hosting all fields of research. On the other hand, their English page has less hits than those of representative observatories in other countries.
- Most of their activities are uni-directional (only outward going). While they do have a facebook page, there is not much use of blogs or social networking. Virtually all activities are aimed at Japanese audience.
- A highlight is the Nobeyama + 188cm telescope. Their visitor program has great contact with the public (locally) and impact. Such open and hosted events are cost effective and should continue. However, they are no substitute for effective use of the web as a way of engaging curious minds of all ages.

Commentary and Recommendations

We feel that NAOJ could be more cost effective by leveraging the web and social media in new ways, making the PRC more 2-way and multi-way. They are missing an opportunity: engagement. An example of a successful astronomy engagement project is the Zooniverse, where the web and social networking are used multi-way to engage the public in "citizen science". The future of NAOJ (and astronomy worldwide) will involve larger and richer data sets in easily searchable databases; already interested members of the public are able to participate in research on-line. We recommend that NAOJ consider inviting Chris Lintott [Zooniverse PI] for a visit. Another idea is a virtual astronomy town meeting, where new phenomena in the sky are discussed. We feel that these would be very effective in Japan, given the high level of interest in astronomy and science generally.

Recommendation 7.3.1: The PRC should make more effort at developing two-way public interaction including using social media tools to interactively engage the public.

Note - the IAU's OAO is hosted at NAOJ but its work was not part of the Review Committee's remit.

8 REPORT ON GROUP D PROJECTS

8.1 Division of Solar and Plasma Astrophysics

The Division of Solar Physics and Plasma Astrophysics (DSPA) consists of four projects, the Hinode Science Center (HSC), the SOLAR-C Project Office (SCPO), the Solar Observatory (SO), and the Nobeyama Solar Radio Observatory (NSRO). We have combined the four programs into one overall evaluation in this report, since there is often considerable synergy between them and the staff involved in the different projects partly overlaps.

Overall evaluation:
- the Hinode Science Center: world leading with outstanding science
- the SOLAR-C Project Office: excellent
- the Solar Observatory: excellent
- the Nobeyama Solar Radio Observatory (NSRO): good

Areas needing further attention -
a) If SOLAR-C is selected size of the group needs urgent attention,
b) ensuring continuity of the time series being obtained at the solar observatory

The External Review Committee finds the performance of Division of Solar and Plasma Astrophysics to be good to excellent, with Hinode being world leading and with outstanding science.

- The great success and the enormous science output of the **Hinode** mission is impressive; it is on course to become one of the most successful solar space missions. A comparatively low-cost mission, it has produced a disproportionately large number of papers. Most of the funding has been provided by ISAS/JAXA, which has greatly leveraged the funding provided by NAOJ.
- Researchers at Japanese universities have been involved in key publications; here NAOJ has provided the infrastructure for successful research at Japanese universities. There has also been international collaboration, with important contributions to the hardware as well as to the science output coming from the USA and Europe.

- The Hinode science center (HSC) appears to be efficiently run and the plan shown to the committee to hand over increasing amounts of Hinode operations to external users (both in Japan and abroad) seems appropriate.
- **The DSPA** has also been developing and building the highly innovative CLASP (Chromospheric Lyman-Alpha Spectro-Polarimeter) rocket experiment, to observe the polarization in the hydrogen Lyman alpha line in the solar spectrum. If successful, this experiment could open up an important new channel for measuring the Sun ' s poorly known chromospheric magnetic field. CLASP is to be launched in August 2015 and is currently being calibrated in a cleanroom facility of the ATC. Impressively, this experiment has been the work of mainly young scientists (students and post docs).
- A detailed proposal for the **SOLAR-C** mission, which can be seen as an extremely powerful follow-up to Hinode, has been written and submitted to ISAS/JAXA. The selection process is underway. If selected by ISAS, SOLAR-C is set to become an even greater asset than Hinode, taking over as the leading solar space observatory. Unlike Hinode, which has significant gaps in its coverage, SOLAR-C will sample the whole solar atmosphere. Like Hinode, SOLAR-C is planned to be a highly international mission, with strong contributions from Europe and the USA, but under Japanese leadership.
- The committee notes that the investment into SOLAR-C has led to a significant reduction in the publication rate by the staff of the Hinode Science Center in recent years, although it remains at an internationally competitive level compared with other solar physics groups. This reduction is regrettable, but reflects the conscious decision of this group to invest in the future at the expense of continuing to maximize the science return from Hinode at NAOJ.
- NAOJ will be the major player in the development of SOLAR-C by being responsible for the assembly, integration, verification (AIV) and calibration of the 1.5 m main telescope of SOLAR-C, the Solar Ultraviolet Visible and Infrared Telescope (SUVIT), which is basically the heart of the mission. The group at NAOJ will also have the PI-ship of the main post-focus instrument, the Spectro-Polarimeter, which will be the key to measuring the magnetic field and the flows in the denser parts of the solar atmosphere. These are major contributions that are in many ways even more challenging than the contributions to Hinode made by the DSPA. This committee is concerned that if SOLAR-C is selected, then the relatively small solar physics group at NAOJ will have to handle not only the Hinode Science Center (in the absence of any accidents probably at least until the launch of SOLAR-C), but will also be responsible for designing, developing (including further development of critical technologies), building and testing major parts of the SOLAR-C mission. If SOLAR-C is selected a strengthening of the team by 2 experienced managers (one for the Spectropolarimeter, one for the main telescope, both of which are complex and highly challenging systems) and a group of dedicated engineers is important. Some strengthening will already be needed during the JAXA study phase starting with the down-selection to 2 missions to be studied in detail from the beginning of the next fiscal year.
- The ground-based **Solar Observatory** in Mitaka runs small solar telescopes that are being constantly upgraded and partly replaced but partly also maintained to keep continuity in the long-term datasets being recorded there. The two main goals of the Solar Observatory, following various important aspects of solar activity over multiple solar cycles as well as the development of technologically new instruments for ground-based solar observations (often together with other institutions in Japan, an example

is the adaptive optics system), are well achieved.

- It is important that time-series that have been compiled over decades are not interrupted, particularly given the increasing realization that solar variability influences the Earth in a variety of ways (e.g. via heliospheric disturbances and variations of the solar radiative output). Breaking off such time series can lead to serious disruptions in our knowledge of the evolution of solar activity, e.g. because the data from another observatory may not be completely comparable. The committee therefore strongly recommends that the time series being gathered at the solar observatory be continued.
- The committee also encourages the Solar Observatory to play an enterprising role in leading the universities' educational and innovative activities.
- **The Nobeyama Solar Radio Observatory (NSRO)** will have closed this March, 2015. However, the operation of the Nobeyama Radio-heliograph (NoRH) will be continued by Nagoya University with international cooperation. The other main instrument at NSRO, the Radio Polarimeters (NoRP) will also be maintained, with technical support by the Nobeyama Radio Observatory (NRO) and with data archival support by the Astronomical Data Center (ADC). As with the solar observatory at Mitaka, it is important to maintain the observation of solar radio flux because of its decades-long history and the information it provides on the long-term variation of solar activity. The committee notes that the transition of the administration of the solar radio instruments to other groups, i.e. Nagoya University and NRO, is a constructive choice both for the community and NAOJ.
- The committee also positively notes the activity by NAOJ staff working to enable observations of the Sun by ALMA which will complement the capabilities of SOLAR-C. However, should SOLAR-C be selected the absence of experienced scientists then working for ALMA will be keenly felt.

Commentary and Recommendations

There were five items recommended in **the last external review** in 2008: For Hinode, (1) a reduction of the operation duty of the staff, (2) support for raising the next-generation researchers; for SOLAR-C, (3) the involvement of specialist project management and engineering staff; for the Solar Observatory, (4) the preparation of a roadmap for ground-based optical solar research with emphasis on collaboration with the future SOLAR-C. All these specific activities have been successfully completed since the last review.

Recommendation 8.1.1: The main recommendation by this committee for the DSPA is that if the SOLAR-C project is selected, then NAOJ should provide the DSPA with the necessary personnel, in particular 2 project managers and the necessary engineers, to ensure that this major project can be successfully completed.

Recommendation 8.1.2: The committee strongly recommends that the time series being gathered at the solar observatory be continued. The committee also encourages the Solar Observatory to play an enterprising role in leading the universities' educational and innovative activities.

9 REPORT ON GROUP E PROJECTS

9.1 Department of Theoretical Astrophysics (DTA)

Overall evaluation - world leading and with outstanding science in several areas
Area needing further attention - stronger encouragement of personnel exchange with universities; more vigorous support for the international visitor program.

The External Review Committee finds that the performance of NAOJ in the DTA project is world leading.

- The DTA has a long history at the NAOJ; it is now the largest group in theoretical astrophysics in Japan. Since its inception, the DTA has been particularly strong in the area of computational astrophysics, and continued strength in this focus area should be a major goal for the future.
- Scientists at the DTA are world leaders in several research topics, for example studies of star/planet formation, radiation hydrodynamics, and numerical simulations of core collapse supernovae. Both the publication and citation rates for work performed at the DTA are very high. Scientists at the DTA are very successful at getting external funding for their work, another indication of excellence.
- The reviewers judged the interaction and synergy of the DTA with rest of NAOJ to be very good. For example, theoretical research on the formation of protostellar cores has motivated new observations of molecular cloud cores with ALMA, while work on planet formation is closely aligned with projects on the Subaru telescope to find and characterize exoplanets.

Commentary and Recommendations

One of the most important roles of the DTA is to train the next generation of theoretical astrophysicists in Japan. Since members of the DTA have less service roles than members of big projects at NAOJ, we judge it important that the DTA continues to lead training through workshops and symposia. The reviewers applaud the leading role the DTA has played in the SOKENDAI, and in the graduate education program at NAOJ in general, and this must continue. The NAOJ encourages personnel exchanges with universities, and indeed many young researchers at the DTA have in fact moved to permanent positions at universities. However, so far this has been accomplished by voluntary effort. To more strongly encourage personnel exchanges, it may be advisable to introduce soft term limits for assistant and associate professors, for example by verbal agreement, or budget reductions after a fixed time limit if necessary.

Recommendation 9.1.1: The DTA should consider some scheme which more strongly encourages personnel exchange with universities.

Overall, we recommend the NAOJ continue strong support for the DTA as a national center for theory. Over the past two years, the number of international visitors has dropped, and this should be reversed. Instead, the DTA should support the international visitor program more vigorously, as it represents one of the best ways for young Japanese scientists to interact with leaders drawn from the international community. We also strongly recommend the DTA continue to host workshops and symposia for the entire Japanese community. We see no reason for the DTA to focus its resources on large, strategic projects, but recommend that members be allowed to pursue their own science. At the same time, it would be wise for

the DTA to prioritize hires in strategic areas related to areas of importance to NAOJ, for example in Big Data relevant to upcoming surveys. Hiring a code developer, perhaps in collaboration with the CfCA, would be an excellent leverage of the strengths of the DTA in computation; however such a programmer must be targeted in an area of science important to the Japanese community. Perhaps the open Associate Professor position could be filled with a hire in these areas. A position to liaise with other groups in NAOJ, which was recommended in **the last external review**, seems less well motivated by this panel, since one person cannot cover the diversity of projects at the NAOJ.

Recommendation 9.1.2: The DTA should support the international visitor program more vigorously and continue to host workshops and symposia for the entire Japanese community.

9.2 Center for Computational Astrophysics (CfCA)

Overall evaluation - world leading with outstanding science
Area needing further attention - replacement of the XC30 and stronger encouragement of postdoc research and publications.

The External Review Committee finds that the performance of CfCA project is world leading.

- From its inception, the NAOJ has provided strong support for computational astrophysics, and the CfCA is a visible outgrowth of that support. The CfCA is now one of the leading computational astrophysics facilities in the world, whose members are not only world-class scientists in their own domains, but also support access to state-of-the-art hardware as well as training and outreach programs for the entire Japanese research community. The CfCA is now a crucial part of the research infrastructure in Japan, and must continue to be supported.
- The list of world-class science projects supported by CfCA resources is impressive. The reviewers took particular note of the fact that 60% of all papers published by Japanese researchers in the area of computational astrophysics used CfCA resources.
- The senior scientific staff at the CfCA are productive and world-leaders in their fields.
- However, in comparison with the DTA, postdocs in the CfCA appear less productive in terms of publications. In order to support their future career path, research and publications by postdocs at the CfCA need to be encouraged more strongly.
- The reviewers judge the interaction and synergy of the CfCA with rest of NAOJ to be outstanding.
- One of its important roles is as a service organization, providing computational support not only for NAOJ, but also for the whole Japanese research community. In these roles it excels, based on the number of users of its machines, throughput of jobs, and number of papers published using CfCA resources.
- Another core role of the CfCA is education and training of young researchers, as well as public outreach. Again, in these topics we judge the efforts of the CfCA as outstanding. The annual schools for programming on High Performance Computing (HPC) systems and scientific visualization are important for Japan to maintain its excellence in computational astrophysics. The CfCA must strongly support these efforts in the future.
- The 4D2U project is impressive, both as a research tool for advanced visualization of results, as well as an outreach project for the public. The demonstration of the facility

was one of the highlights of the review. We applaud the CfCA for undertaking this initiative, and recommend it keep close track of the usage statistics to measure its success.

Commentary and Recommendations

The response of the CfCA to the recommendations of **the last external review** have met or exceeded expectations. For the future, it is crucial that the XC30 be replaced in 2018, or the CfCA runs the risk of becoming obsolete. It is certain that computation will only continue to grow in importance as a tool in theoretical astrophysics, and the NAOJ must work to ensure the resources provided to the national community through the CfCA remain world-leading. The plan to develop an open code in Japan for Japanese researchers (perhaps in collaboration with the DTA) is a worthy goal, but must be motivated by specific science goals. In the meantime, the CfCA should provide support and training in other open source numerical codes. While the development of the GRAPE hardware for N-body simulations stands as one of the greatest success stories of the CfCA, changes in commercially available hardware (particularly Graphics Processing Unit, GPUs) has made this project less attractive. The CfCA did not provide a compelling argument for continued support of this project, and we recommend it be phased out.

Recommendation 9.2.1: The XC30 should be replaced in 2018 and NAOJ should ensure that the resources provided by CfCA remain world-leading.

Recommendation 9.2.2: In order to support the future career path of postdocs at the CfCA, their research and publications need to be encouraged more strongly.

10 RECOMMENDATIONS (Merged)

10.1 Core Projects

ALMA

4.1.1: NAOJ continues its major, highly successful role in ALMA, putting in further resources if required; the involvement of other countries in the region should be increased.

4.1.2: Although significant effort has already been made, effort to further improve the safety/security of staff at NAOJ Chile Observatory should be continued and enhanced in the future.

Subaru

4.2.1: The program to decommission older instruments, reduce the number of instrument changes, operate more with higher impact instruments and with more survey mode observations should be pursued. PI-type instruments should be selected with care.

4.2.2: The program to enlarge the East Asian user community should continue. Exchanges of time with other Mauna Kea telescopes should continue.

4.2.3: We urge more resources in terms of budget and staff resources for (a) safety/risk management; and (b) overall facility preventive maintenance and upgrades.

Thirty Meter Telescope (TMT)

4.3.1: NAOJ is encouraged to watch for opportunities for further Japanese involvement and seize them whenever possible.

4.3.2: NAOJ is encouraged to take a more active role in TIO governance and high-level policy development. Close collaborations with all stakeholders should be developed.

4.3.3: The organization of TMT-J should be reviewed as a priority and simplified where possible; it will need extending and strengthening as the project grows.

Mizusawa VLBI Observatory

5.1.1: A plan for the Mizusawa observatory has to be developed.

Nobeyama Radio Observatory (NRO)

5.2.1: Old instruments should be decommissioned as planned to reduce the burden on NRO staff, and solving the remaining potential single point failures should be given high priority.

5.2.2: Consideration has to be given to the role that the 45-m telescope should play in the ALMA era.

RISE (Research of Internal Structure and Evolution of Solar System Bodies)

5.3.1: The data from KAGUYA and Hayabusa 2 should continue to be exploited.

10.2 Group B Projects

Jasmine

6.1.1: The Jasmine team develops a more thorough understanding of the data processing, with the goal of the processing being done at NAOJ.

6.1.2: We recommend adaptations are made to the small-Jasmine project such that it can reach to fainter magnitudes. Depending on the current mission limitations, these adaptations could be to the spacecraft and payload design, the detectors and electronics, or even the data collection and analysis.

Okayama Astrophysical Observatory (OAO)

6.2.1: An overall operations, maintenance, and development plan for OAO should be developed. In particular, the 3.8-m operations phase agreement with Kyoto University should be worked out.

Extrasolar Planets

6.3.1: We recommend an increase in FTE level for the scientific interpretation of the data and continuation of the developments and exploitation of the IR imaging techniques as planned.

Gravitaional Waves (KAGRA)

6.4.1: We recommend that over the next five years the KAGRA project (as a whole) has sufficient funds and staff so that:

(i) The strength of directly detected gravitational waves (or an astrophysically meaningful upper limit on the strength of gravitational waves) are well determined
(ii) The position of any source is localised as well as possible when combined with all other operating detectors
(iii) The contribution of the special features of KAGRA to its sensitivity - i.e. underground operation to improve the low frequency response, the cryogenic mirrors and the vibration isolation system - are understood and recognised
(iv) The contribution of KAGRA to the GW network (primarily sky location and sensitivity) is recognised and understood

6.4.2: Future developments are contingent upon the direct detection of gravitational waves (via multi-detector coincidence).

10.3 Group C Projects

Advanced Technology Center (ATC)

7.1.1: There is a continuing need to focus staff resources (including hiring professional engineers) on the scientifically highest ranked projects which will have the broadest impact in astronomy. This will be critically important in the next 5 years. ATC should work with NAOJ closely to make smooth changes in the staff.

Astronomy Data Center (ADC)

7.2.1: We recommend that the expected growth of this area is monitored and the extra resources necessary to keep this key centre functioning are anticipated. We recommend more collaboration with other data-intensive astrophysics efforts worldwide.

Public Relation Center (PRC)

7.3.1: The PRC should make more effort at developing two-way public interaction including using social media tools to interactively engage the public.

10.4 Group D Projects

Division of Solar and Plasma Astrophysics

8.1.1: The main recommendation by this committee for the DSPA is that if the SOLAR-C project is selected, then NAOJ should provide the DSPA with the necessary personnel, in particular 2 project managers and the necessary engineers, to ensure that this major project can be successfully completed.

8.1.2: The committee strongly recommends that the time series being gathered at the solar observatory be continued. The committee also encourages the Solar Observatory to play an enterprising role in leading the universities' educational and innovative activities.

10.5 Group E Projects

Department of Theoretical Astrophysics (DTA)

9.1.1: The DTA should consider some scheme which more strongly encourages personnel exchange with universities.

9.1.2: The DTA should support the international visitor program more vigorously and continue to host workshops and symposia for the entire Japanese community.

Center for Computational Astrophysica (CfCA)

9.2.1: The XC30 should be replaced in 2018 and NAOJ should ensure that the resources provided by CfCA remain world-leading.

9.2.2: In order to support the future career path of postdocs at the CfCA, their research and publications need to be encouraged more strongly.

10.6 Other Recommendations

10.1: We recommend that heads of units should be made aware of the full staff costs of their unit, even if they do not have control over all those resources.

10.2: We recommend that funding to hire post-docs is protected.

10.3: We encourage the Observatory to take advantage of the current opportunity to advertise women-only positions to recruit some more excellent female scientists. We also recommend that in future disaggregated staff numbers are recorded (i.e. the male and female numbers are reported separately). We further recommend that NAOJ strengthens the international/cultural diversity of its staff.

Acknowledgements

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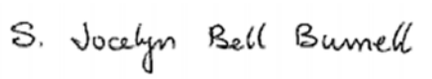
Appendix A Membership of the Panel



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Appendix B Abbreviations and Acronyms Used

ACA	Atacama Compact Array (Morita Array)
ADC	Astronomy Data Center
AFTA	Astrophysics Focused Telescope Assets (of WFIRST)
ALMA	Atacama Large Millimeter/submillimeter Array
AOS	Acousto-optical Spectrometer
APOGEE-2	APO Galaxy Evolution Experiment 2, a component of SDSS-IV
ASC	NAOJ/East Asia ALMA Support Center
ASIAA	Academia Sinica Institute of Astronomy and Astrophysics
ASTE	Atacama Submillimeter Telescope Experiment
ATC	Advanced Technology Center
BBMs	Bread Board Models
CfCA	Center for Computational Astrophysics
CLASP	Chromospheric Lyman-Alpha Spectro-Polarimeter
DSPA	Division of Solar Physics and Plasma Astrophysics
DTA	Department of Theoretical Astrophysics
EAO	East Asian Observatory
EAVN	East Asian VLBI Network
ESA	European Space Agency
ESAC	European Space Astronomy Centre
ESO	European Southern Observatory
ESPO	Extrasolar Planet Project Office
FOREST	FOur beam REceiver System on 45m-Telescope
FTE	Full-time equivalent [staffing level]
GPI	Gemini Planet Imager
GPU	Graphics Processing Unit
GRAPE	GRAvity PiPE; special-purpose computer dedicated to gravitational computations
GRB	Gamma Ray Burst
GW	Gravitational Wave
GWPO	Gravitational Wave Project Office
HIDES	High Dispersion Echelle Spectrograph
HPC	High Performance Computing
HSC	Hinode Science Center *or* Hyper Suprime-Cam
HST	Hubble Space Telescope
IAU	International Astronomical Union
ICCR	Institute for Cosmic Ray research (University of Tokyo)
ILOM	In-situ Lunar Orientation Measurement telescope
IR	Infrared
IRD	Infrared Doppler Instrument for Subaru
IRIS	Infrared Imaging Spectrograph (for TMT)
ISAS	Institute of Space and Astronautical Science; now part of JAXA
ISDTs	International Science Development Teams (of TMT)
JAO	Joint ALMA Observatory
JASMINE	Japan Astrometry Satellite Mission for INfrared Exploration
JAXA	Japan Aerospace Exploration Agency

JUICE	Jupiter Icy Moons Explorer (Proposed ESA mission to Jupiter's Icy Moons)
JVN	Japanese VLBI Network
JVO	Japanese Virtual Observatory
KAGRA	Kamioka Gravitational Wave detector
KAGUYA	SELENE's Japanese name
KASI	Korea Astronomy and Space Science Institute
KaVA	The joint KVN and VERA Array
KEK	High Energy Accelerator Research Organisation
LCGT	Large Scale Cryogenic Gravitational Wave Telescope (now KAGRA)
LIDAR	Light Detection and Ranging
LIGO	Laser Interferometer Gravitational Wave Observatory (USA)
LiteBIRD	Proposed Japanese satellite to study B mode polarization of Cosmic Microwave Background
LLR	Lunar Laser Ranging experiment
MAST	Mikulski Archive for Space Telescopes
MELOS	Mars Exploration with a Lander-Orbiter Synergy - proposed Japanese Mars Lander/Rover
MKIDS	Microwave Kinetic Inductance Detectors
MOU	Memorandum of Understanding
Mpc	Megaparsec = one million parsecs or 3.26 million light years
NAOJ	National Astronomical Observatory of Japan
NINS	National Institutes of Natural Sciences of Japan
NIR	Near Infrared
NoRH	Nobeyama Radio Heliograph
NoRP	Nobeyama Radio Polarimeter
NRAO	National Radio Astronomy Observatory (USA)
NRO	Nobeyama Radio Observatory
NSF	National Science Foundation (USA)
NSRO	Nobeyama Solar Radio Observatory
OAO	Okayama Astrophysical Observatory *or* IAU's Office for Astronomy Outreach at NAOJ
PFS	Prime Focus Spectrograph
PI	Principal Investigator
PRC	Public Relations Center
R&D	Research and Development
RISE	Research of Internal Structure and Evolution of Solar System Bodies
SCPO	SOLAR-C Project Office
SDSS	Sloan Digital Sky Survey
SEEDS	Strategic Exploration of Exoplanets and Disks with Subaru
SEIT	Second Earth Imager for TMT
SELENE	Also known as KAGUYA; lunar orbiter spacecraft
SIS	Superconductor-Insulator-Superconductor (mixer)
SKA	Square Kilometer Array
SMOKA	Subaru-Mitaka-Okayama-Kiso Archive System
S/N	Signal to noise ratio
SO	Solar Observatory
SOKENDAI	Graduate University for Advanced Studies
SPHERE	Spectro-Polarimetric High-contrast Exoplanet REsearch instrument

SSPs	Subaru Strategic Programs
SUVIT	Solar Ultraviolet Visible and Infrared Telescope
TES	Transition Edge Sensor (bolometer)
TIO	Thirty Meter Telescope International Observatory
TMT	Thirty Meter Telescope
TMT-J	Thirty Meter Telescope Japan project
VERA	VLBI Exploration of Radio Astrometry
VIRGO	European Gravitational Wave Interferometer (located in Italy)
VLBI	Very Long Baseline Interferometer
VLT	ESO's Very Large Telescope
WACO	WFIRST AFTA COronagraph
WFIRST	Wide Field Infrared Survey Telescope
WFOS	Wide Field of View Optical Spectrometer (for TMT)
XC30	Supercomputer "ATERUI" nicknamed by CfCA
2SB	dual Sideband
4D2U	Four-dimensional Digital Universe project

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