1 NWO aanvraag apparatuur-middelgroot sterrenkunde

1.1 Project title: Speckle Processor for the Dutch Open Telescope

1.2 Project acronym: DSP = DOT Speckle Processor

1.3 Principal investigator: R.J. Rutten

2 Summary

This application requests funding to install a k€ 188 "DOT Speckle Processor" (DSP) at the Dutch Open Telescope (DOT) on La Palma in order to fully exploit the unique niche of this telescope in worldwide solar physics.

The DOT is a revolutionary optical telescope yielding superb high-cadence image sequences of the solar surface, reaching diffraction-limited angular resolution ($0.2''$) over a wide field of view. It is presently being equipped with a six-camera multi-wavelength imaging system which turns the DOT into a tomographic mapper, sampling the solar atmosphere synchronously from the deep photosphere to the high chromosphere. This capability opens front-line opportunities to study the magnetic coupling between the solar interior and the solar corona, widely regarded as a key area in solar physics and space weather research.

The requested 112-CPU processor will remove the severe bottleneck in the DOT speckle reconstruction which presently limits DOT utilisation to only a few two-hour tomographic observing runs per year. It will enable frequent eight-hour runs, and so permit "opening the DOT" to the wider (national and international) community as a general facility for high-resolution solar tomography, to be exploited in frequent DOT partnership in multi-telescope campaigns by combining peer-review time allocation with a hands-on-telescope student education programme.

3 Classification

Astronomy, subdiscipline Solar Physics (A&A 06)

4 Composition of the research team

name	title	specialty	employer	period
programme leader	Prof. Dr.	solar physics	UU (full professor)	search started
R.J. Rutten	Prof. Dr.	solar physics	UU (UHD), ITA (Prof. II)	until medio 2007
R.H. Hammerschlag	Dr. Ir.	optics/mechanics	UU (UD)	until 2009
P. Sütterlin	Dr.	solar physics	UU (NWO–GB/E)	until 30-4-2004
K. Tziotziou	Dr.	solar physics	UU (EC-ESMN)	01-03-2003 − 30-09-2005
F.C.M. Bettonvil	Ir.	optics/mechanics	ASTRON (NWO–GB/E)	until 30-09-2005
A.G. de Wijn	Drs.	astrophysics	UU (AIO)	until 30-09-2006
candidate identified	Drs.	astrophysics	UU (AIO)	01-09-2003 − 30-08-2007

All 100% involved in DOT research, except teaching obligations. PhD supervision is by Rutten.

5 Embedding

Utrecht solar physics is part of NOVA; the DOT effort is co-funded by NOVA. NWO supports the DOT under Project 614.021.017, previously under Project 614.021.011. The present proposal implies a hardware extension to the current grant. Solar physics recently became a separate research programme at the Faculteit Natuur- en Sterrenkunde of Utrecht University, led ad-interim by Rutten while a full professor "solar physics" is being sought in order to enlarge Utrecht solar physics the coming years. However, solar physics remains integrated in the Sterrekundig Instituut Utrecht apart from Faculty financing. Rutten is also visiting professor at the Institute of Theoretical Astrophysics of Oslo University, coordinator of the EC-RTN European Solar Magnetism Network (ESMN, 2003–2007), and coordinator of an INTAS grant for East-West collaboration (2002–2004).
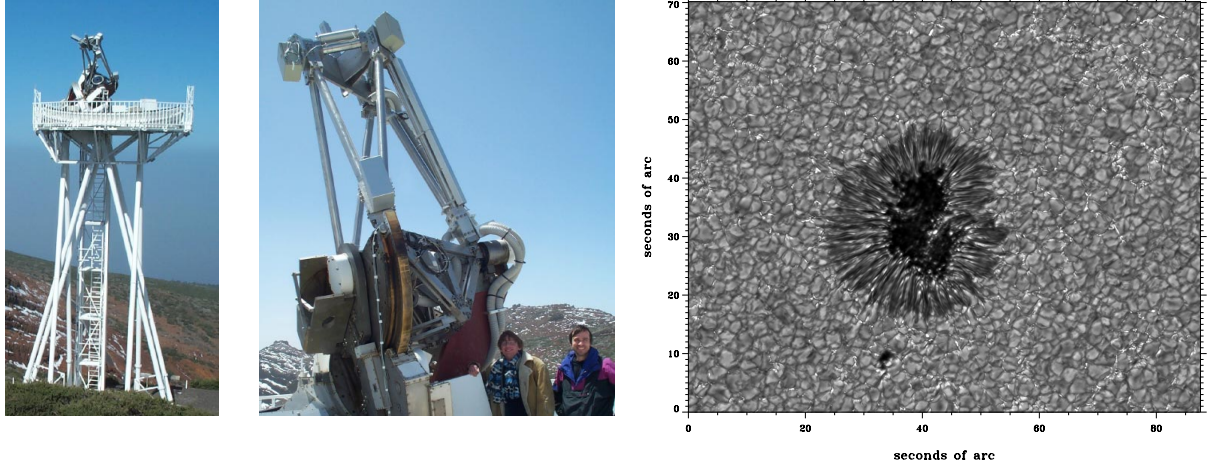
Figure 1: *The Dutch Open Telescope on La Palma. The DOT is open and is mounted on a 15 m high open tower to exploit the superior atmospheric seeing at La Palma brought by the continuous oceanic trade winds. The clamshell bad-weather canopy is folded away in these views. Left: open tower with open telescope. The 45 cm parabolic primary mirror is seen at the center of the telescope structure. The post-focus system is mounted at the telescope top (middle panel). A on-axis tube contains a water-cooled prime-focus field stop, re-imaging and beam-splitter optics, and the G-band CCD camera. Five more cameras are being mounted with elaborate filter optics on the heavy support struts besides the incoming beam. The digital image stream is transported through fibers to the control room in the Swedish telescope building. Right: sample image analysed by Sütterlin (2001).*

6 Description of the proposed research

In brief, this proposal requests k€ 141 from NWO for a k€ 188 image processing system on La Palma that will accelerate the DOT speckle restoration tremendously through state-of-the-art computer hardware. It will allow orders-of-magnitude more frequent telescope utilisation and enable full exploitation of the DOT capability for superb tomographic solar-atmosphere mapping, in particular in international multi-telescope campaigns involving EUV and X-ray observing from space.

The DOT website (`http://dot.astro.uu.nl`) furnishes DOT images, movies, DOT photographs, background information, plus access to DOT articles, reports, and presentations.

6.1 DOT overview. The Dutch Open Telescope (DOT) on La Palma is an innovative solar telescope which successfully achieves sustained high-resolution imaging of the solar surface. It yields superb image-sequence quality by combining an open design at a superior wind-swept site (Fig. 1) with elaborate image processing using speckle reconstruction.

The DOT was designed and built by Hammerschlag with coworkers at Utrecht and the university workshops at Delft and Utrecht. The open concept was revolutionary. So far, all high-resolution solar telescopes use evacuation to avoid internal turbulence caused by internal solar heating. The open DOT instead relies on telescope flushing by the strong laminar trade winds which make La Palma a world-class solar site. The DOT's successful demonstration of this principle spawned a wave of new large-telescope projects elsewhere[1].

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[1] The new open telescopes break the 1-m limit imposed on vacuum windows and refractor objectives by glass technology. The newly rebuilt Swedish 1-m Solar Telescope (SST) on La Palma, from whose building the DOT is operated, is at 1-m the largest feasible refractor. It pioneers in being the first solar telescope reaching 1-m resolution ($0.1''$ in the visible; Scharmer et al. 2002). The SST uses adaptive optics to correct the seeing, a complementary technique to the DOT's speckle reconstruction which works in the pupil plane instead of the image plane. It does so in real time, but optimally only for the central isoplanatic patch. With the DSP in place at the DOT, tandem SST–DOT operation is likely to be scheduled very frequently, with the SST furnishing $0.1''$ resolution at field center and the DOT wider-field tomographic context at $0.2''$. All other large-telescope projects concern open reflectors. They are, in brief, the German 1.5 m GREGOR for Tenerife (funded; first light around 2005), the 1.6 m New Solar Telescope for Big Bear Solar Observatory (being proposed), the 1 meter Indian MAST for Udaipur Solar Observatory (proposed), and the 4 meter American ATST (first tranche NSF-funded, site selection including La Palma started, first light around 2010). They mostly target adaptive-optics spectropolarimetry. The DOT team assists actively in all projects (guider and turret hardware of the SST; GREGOR dome fabrication at the TUD; MAST, NST and ATST design discussions). An upgrade of the DOT to 1.4-m aperture in 2006 is being proposed in NOVA-2 context.

The initial DOT G-band movies (on the DOT website) are widely acclaimed as superb. They dramatically convey the dynamical nature of the magnetically-dominated structure of the solar atmosphere and demonstrate forcefully that high-resolution large-field high-cadence long-duration observation is a must in solar physics. Of particular importance is their excellent temporal homogeneity. When the La Palma seeing is good enough for speckle restoration up to the $0.2''$ diffraction limit (which occurs fairly frequently), an entire multi-hour image sequence consistently possesses diffraction-limited resolution. The solar-physics emphasis on magnetic field evolution and dynamics (see below) makes such unprecedented seeing-free homogeneity essential.

6.2 DOT tomography. The DOT is presently being equipped with multi-wavelength optics feeding six synchronously-operated cameras with dual fiber-optic links to the control and data-acquisition computers in the Swedish building. The first two channels (blue continuum and G band) are working. The Ca II H and red continuum channels follow this spring. The remaining two come this summer and autumn. The latter will use sophisticated tunable birefringent Lyot filters for sampling the profiles of Hα and Ba II 455.4 nm, on loan from the Canadian Research Council and the Institute of Solar-Terrestrial Physics at Irkutsk. The six synchronous channels together constitute tomographic sampling of the solar atmosphere from the deep photosphere (continua and G band) through the low chromosphere (Ca II and Ba II, the latter especially for Dopplershift) to the high chromosphere (Hα). Complementary EUV and X-ray observation from space will add coronal topology and dynamics.

6.3 Tomographic solar physics. Solar physics is primarily directed towards gaining understanding of the complex magnetohydrodynamical nature of solar activity. Solar magnetic fields are generated by enigmatic dynamo processes in the solar interior, organised into intricate activity patterns in the photosphere, dominate the structure of the chromosphere and corona at any scale, regulate the solar wind, and affect the extended heliosphere including near-earth space weather and the terrestrial climate. Solar physics presently flourishes in a remarkable renaissance thanks to continuous high-cadence space observing (SOHO, TRACE), increasingly realistic numerical simulations, increasing interest in space weather and new groundbased observing techniques. This proposal exploits the latter to give Dutch astrophysics a unique observational position in this renaissance, adding to the theoretical solar-physics expertise at Rijnhuizen and Nijmegen.

The general solar-magnetism context is threefold. To astrophysics, solar magnetism provides a close-up example not only of magnetism in other stars but also in accretion disks, cataclysmic variables, galactic nuclei, etc. This link characterizes the solar interest at Nijmegen (Prof. Dr. J.M.E. Kuijpers). The solar interest at FOM Rijnhuizen (Prof. Dr. J. Goedbloed and Dr. R. Keppens) arose because terrestrial plasma confinement machines such as Tokamaks do not reach the scales, densities and temperatures exhibited in the solar atmosphere. Coronal physics therefore complements plasma-instability research in fusion research. Finally, space weather (shorthand for the solar influence on the near-earth environment and the earth's climate) is dominated by solar magnetism and links the latter to its economical and social consequences. It is a rapidly growing research area in the USA, with Europe starting to follow.

High-resolution observation of solar magnetism is of key importance to all three research areas. At the solar surface, the field displays patterning imposed by the subsurface dynamo and convective flows while, at the same time, it controls flows and wave motions to the outer atmosphere. This flip in domination requires studies of the magnetic field structure and dynamics simultaneously in the photosphere and the overlying chromosphere. The DOT is specifically suited to sample both regimes at high angular resolution in high-cadence time sequences. The DSP will enable us to achieve such tomography frequently and over relatively long durations. It is hard to think of a magnetism-oriented solar observing program the coming years that is not likely to gain from adding such DOT multilayer mapping to other diagnostics such as spectropolarimetry, radio observation, and short-wavelength imaging and spectroscopy. Frequent partnership in multi-telescope campaigns will give the DOT worldwide impact.

Our own solar physics interests are evolving from wave physics (e.g. Krijger et al. 2001, Hoekzema et al. 2002) and photospheric fine structure and dynamics (e.g. Sütterlin 2001, Sobotka and Sütterlin 2001, Nisenson et al. 2003, Rouppe van der Voort et al. 2003) to chromospheric structuring and the enigmatic field transition from photospheric flux tubes to coronal loops. The latter form the principal topic of theoretical investigations at Rijnhuizen, but their photospheric footpoint constraints are so far badly known. We expect that especially the DOT Hα channel will provide important insights in such magnetic-coupling research, as it also will for the strong prominence-physics interest at Nijmegen. ESMN
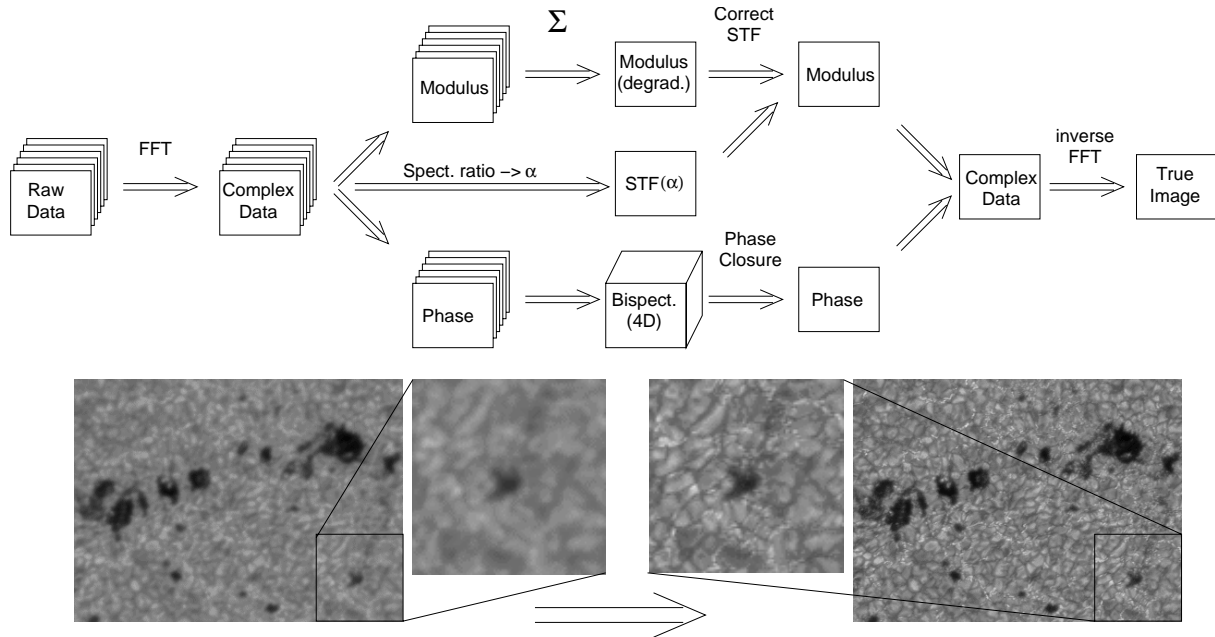
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Figure 2: Schematic illustration of speckle reconstruction. The Fourier amplitudes and phases are treated independently, employing the spectral ratio technique to restore amplitude spectra and phase closure to restore phase spectra. The technique requires a speckle burst of 100 frames taken at 10 frames/s with exposures below the seeing-freezing time of 10 ms, representing independent samples of the wavefront distortions. A burst must be completed within the time in which the solar scene does not change, 20–30 s when set by the gasdynamical sound speed. In the initial pre-processing, all frames of a burst are co-aligned ("tip/tilt correction") and the full field of view is tessellated into about a thousand subfields, each smaller than the isoplanatic patch over which the atmospheric wavefront perturbations do not vary with angle. The speckle reconstruction is done independently for each subfield, using all burst frames. The post-processing merges all restored subfields to a single sharp image. Local correlation tracking is applied to the full image sequence to correct small subfield mismatches. The resulting sequence is usually also space-time Fourier-filtered to remove "solar seeing" consisting of the global solar five-minute oscillations.

postdoc Tziotziou was selected precisely for his expertise in Hα interpretation.

6.4 DOT speckle processing. Correction of the wavefront perturbations caused by the Earth's atmosphere is now an absolute must in optical solar physics. There are three methods: speckle reconstruction, phase-diverse imaging plus speckle reconstruction, and adaptive optics (AO). Speckle reconstruction was chosen for the DOT because it delivers relatively good restoration over the whole field of view defined by the camera chips, presently one thousand isoplanatic patches. In addition, speckle reconstruction is the only technique that fits the DOT optomechanical constraints and our relatively low budget and manpower. The disadvantage is the laborious post-detection processing.

Figure 2 illustrates the three-phase procedure. The DOT speckle code uses the speckle masking formulated by Weigelt (1977) and Hofmann and Weigelt (1986), as implemented at Göttingen (de Boer 1993) and improved and ported to Utrecht by Sütterlin. Because speckle exposures of 10 ms have insufficient S/N in Hα and Ba II 455.4 nm narrow-band images, Sütterlin has adapted the two-channel restoration technique of Keller and von der Lühe (1992) for these. It employs a wider passband in the neighbouring continuum to derive and correct for the atmospheric modulation transfer function.

6.5 DOT speckle bottleneck. Our present computers on La Palma cannot store or handle the data stream when all six cameras will be operational. One single frame of 1296×1030 px^2 represents 2.7 Mbyte; at 30 s burst cadence, one camera deposits 33 Gbyte/hour; a "run" of all 6 cameras during 8 hours amounts to 1.6 Tbyte.

The DOT presently has 72 Gbyte storage per camera, permitting runs of only two hours. The data are now archived overnight on an Exabyte Mammoth-2 7-tape library. The subsequent tape processing on the present DOT cluster (14 600-MHz CPU's) is done remotely from Utrecht and takes, per burst, about

15 min for pre-processing, 15 min for the speckle reconstruction part (with subfields divided between computers), and 5 min for the post-processing. With all six cameras, a two-hour run will need at least one month of wall-clock time on our present system – a ratio of 350 between observing duration and processing duration.

Upshot: the speckle processing becomes a terrible bottleneck. It does not fully kill our own DOT science utilisation because just one good tomographic run on an active region, plage, or even a quiet solar area is likely to contain enough material for a complete PhD thesis (as was the case with two famous image sequences from the previous Swedish telescope during the past decade). However, the bottleneck obviously inhibits offering DOT observing time to others, nationally or internationally, on anything more than a very modest scale. It inhibits exploiting the full potential science niche that DOT tomography offers.

In addition, two-hour sequence duration per day is really too short for many evolutionary processes such as flux emergence and sunspot breakup, and for hunting to catch relatively rare and briefly-lasting dynamical phenomena such as pore formation, lightbridge collapses, filament eruptions, and above all flares.

When opting for speckle reconstruction, we anticipated that large-throughput speckle reconstruction should eventually become affordable by the steadfast decline in CPU price/performance ratio (Moore's law). At the same time, this decline motivated us to wait until the last possible moment in order to get more speed for money. With the imminent completion of the 6-camera DOT tomography system, that moment has arrived. Hence this DSP proposal at this time.

7 DSP description

Preparatory work in this direction started two years ago. The DOT speckle code was ported to C and rewritten into a parallel version by de Wijn[2]. He performed extensive tests on parallel clusters which demonstrated that the speckle reconstruction part parallelizes almost perfectly, but that the pre- and post-processing are hard to parallelize. Detailed performance analysis of these tests and intensive discussions with external experts[3] led to the architectural design proposed here, a hybrid distributed/parallel 112-processor farm to be put on La Palma where it will enable overnight processing of the daily DOT harvest. It is not realistic to think of processing the DOT speckle stream elsewhere. Transfering 1.6 Tbyte data transfer per observing day via the Internet remains impossible in the foreseeable future; tape transfer is far too time consuming.

7.1 DSP configuration. The proposed DSP is a hybrid with a large-storage master computer splitting processing over five main modules. Pre- and post-processing is handled on a fast machine with considerable memory capacity, the speckle reconstruction per subfield being farmed out to 20 low-memory processors. The architecture is shown in Fig. 3. The strawman configuration with detailed cost specification is given in Table 1.

We are confident that this configuration will do the job. Our speckle experience and parallel-test analysis indicates that, together with well-defined software upgrades, it will be over two orders of magnitude faster than our present system and will reach the processing/observing ratio of only a factor three needed for overnight processing of a full 6-camera 8-hour run at 30 s cadence.

7.2 Heat dissipation control. The heat generated by the DSP represents a major concern. Since the world-class quality of the SST and DOT images capitalizes on the superb La Palma daytime seeing, a source of appreciable heat cannot be tolerated near the telescopes. In particular, we are rightfully forbidden by SST director G.B. Scharmer (who hosts the DOT team most graciously in his building) to release 10 kW of DSP heat inside or near his building. We fully support his veto. Our solution, which has his explicit approval, is twofold: *(i)* to put the DSP in a shed about 100 m from the DOT in the opposite direction to the SST (60 m), and *(ii)* to store the DSP heat initially in water and release it primarily around sunset and sunrise, minimising bad effects on both the daytime and the nighttime seeing.

The DSP power consumed by its 112 CPU's (7000 W), 112 memory modules (300 W), 60 disks (900 W), and 5 switches (250 W) adds up to about 9 kW. At 75% power-supply (PSU) efficiency the total heat to be handled amounts to over 11 kW. Each CPU and each PSU gets a water-cooled heatsink.

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[2] As graduation research in computational physics with Dr. Ir. A. van der Steen (de Wijn also graduated in astronomy).
[3] Dr. Ir. A. van der Steen of Utrecht University and Dr. M. van Noort of Oslo University. Both are willing to assist likewise in the DSP procurement and implementation.
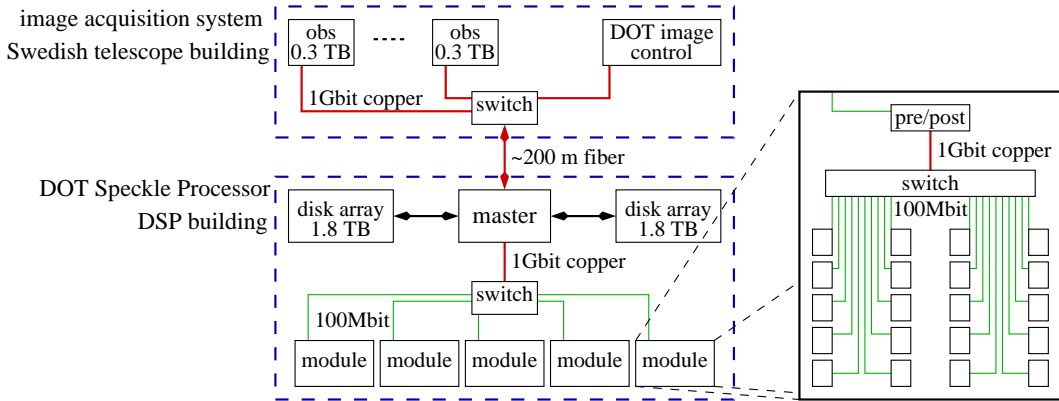
Figure 3: DSP architecture. The upper boxes (obs) denote the image-acquisition computers, one per camera, each to be upgraded with 0.3 Tbyte storage and a fast connection. They and the DOT control workstation are located in the DOT observing room in the basement of the Swedish SST building. A 1 Gbit switch will pipe the data stream through 200 m long optical fibers to the DSP in a shed located well away from both the DOT and the SST to avoid local seeing deterioration. The master computer has storage for two full observing runs, and distributes the processing over five modules. The latter are completely diskless. The head node in each module has a large memory capacity to handle the pre- and postprocessing, and shares out the speckle reconstruction per subfield to 20 low-memory CPU's.

Our conservative computations show that we need two water tanks of 3 m^3, and two 30 kW outdoors heat exchangers to cool the water at the end and the start of the day.

This solution requires data transport through optic fibers from the Swedish SST building to the DSP housing, similar to fibers which already transport the DOT image stream from the DOT to the control room in the SST building.

7.3 Assembly, transport, installation. We deem it absolutely necessary to assemble at least part of the DSP (master and a module) in Utrecht for extensive testing including software optimization. We have been and are in contact with large international and smaller local firms offering turn-key solutions or at least partial delivery including assembly, but so far find that their prices are far too high. We are prepared to take care of the DSP assembly ourselves (including a good supply of computer-interested students) but of course will prefer outsourcing and so will continue our search for a firm offering both good price/performance and reliability.

Transport is likely to be best per container in view of the voluminous heat storage and release system. We do not anticipate problems in installing or adapting an existing shed for the DSP housing.

7.4 Time schedule. Time schedule: DSP procurement and testing are foreseen for the coming autumn and winter, with transport to and installation on La Palma in early spring in order to be ready for the 2004 best-seeing season[4], when we plan to start (inter-)national DOT time allocation as well as a DOT traineeship programme (see below).

7.5 DSP utilisation. An operational DSP will permit us to open the DOT for common-user and service-time allocation to the wide solar physics community. We aim at peer-review DOT time allocation, either requiring that the proposer comes to La Palma to help observing, or scheduling our own observing stints to fit the proposer's suggestions. The normal mode will be collaborative with data and authorship sharing. The external colleagues will receive the reduced DOT data per DVD[5].

We also intend to achieve more frequent DOT observing by supplementing our meager manpower by initiating a "DOT student education" programme. It will consist of two-week traineeships at the telescope

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[4]May through October; superb seeing may occur at any time, but its frequency tends to be highest in early summer and early autumn.

[5]Speckle processing represents hundred-fold data compression, from 100 frames to one image per burst. One cannot mail 1.5 TB of raw speckle data with a copy of the speckle code to a prospective client and then expect productive science usage. On-site processing reduces the data size to only 15 GB per full eight-hour six-camera run, easily mailed as DVD's and easily inspectable with the client's workstation. Note that the La Palma connections are limited to 2 Mb/s, in practice only up to 20 KB/s in daytime.

part, item	nr, type	firm, model	cost 1x	subtotal	total
image acquisition					
disks	24x 73 GB	73 GB Hitachi IC35L073	€ 370	8 880	
switch	1x 8p Gb	Netgear GS108	500	500	
network card	7x Gbit	D-Link DGE-500T	70	490	
transceiver	1x copper-fiber	Mini5 M5-1000TSC	250	250	€ 10 120
DSP master					
motherboard	1x Dual Athlon	Tyan K7X Pro S2469UGN	600	600	
CPU's	2x AMD Athlon	Athlon MP 2200	300	600	
memory	2x 512 MB	Infineon 512 MB regist. ECC	230	460	
disks	1x 3.5 TB RAID 5	62x 73 GB Hitachi IC35L073	370	22 940	
controller	1x RAID	Adaptec 3410S 4-channel	1 550	1 550	
network card	1x 1 Gbit fiber	Netgear GA621	300	300	
disk enclosures	8x 19" cabinets	8-disk SCSI	320	2 560	
enclosure	1x 19" enclosure	1HE	500	500	29 510
1/5 DSP pre/post					
motherboard	1x Dual Athlon	Tyan K7X Pro S2469UGN	600	600	
CPU's	2x AMD Athlon	Athlon MP 2200	300	600	
memory	4x 512 MB	Infineon 512 MB regist. ECC	230	920	
enclosure	1x 19" enclosure	1HE	500	500	13 100
1/100 DSP node					
motherboard	1x Single Pentium 4	ASRock G Pro	90	90	
CPU's	1x Pentium 4	Intel PIV 2.4 GHz	250	250	
memory	1x 128 MB	128 MB DDR PC266	35	35	
network card	1x 100 Mbit	D-Link DFE530TX	25	25	
power supply	1x	micro-ATX 235 W	50	50	45 000
DSP infrastructure					
racks	5x 19" racks	42HE	1 000	5 000	
switches	5x 24p 100 Mb/1p 1 Gb	Netgear FS726 + AG711T	550	3 300	
UPS	1x 10 kW UPS	Elinex Powerware	9 400	9 400	
DVD writer	1x autoloading	not yet identified	2 000	2 000	
odds & ends	patch+powercables etc.			1 000	20 700
image transfer					
fibers	1x 12-fiber cable		1 000	1 000	
labour	groundwork	local		7 000	8 000
heat release control					
water storage	2x 3 m^3	RLM	2 000	4 000	
outdoors exchangers	2x 30 kW	Helpman	3 500	7 000	
CPU exchangers	112x 60 W	Thermaltake	100	11 200	
PSU exchanger	1x 2.5 kW	in-house	3 000	3 000	
DSP water pumps	2/module	Lowara	200	2 000	
release pumps	2x	Lowara	2 000	4 000	
odds & ends	tubing etc.			7 000	38 200
installation					
housing	acquisition, adaptation			pm	
transport	1 container		10 000	10 000	
travel	6x DSP, 5x heat release	2-week stay	1200	13 200	23 200
grand total					€ 187 830
matching					47 000
request					140 830

Table 1: Strawman and cost specification. Image acquisition: upgrade existing computers in Swedish building. DSP master: dual-CPU master computer feeding 5 modules. DSP pre/post: dual-CPU pre- and postprocessor, one per module. DSP node: single-CPU parallel speckle processor, 20 per module, 100 in total. DSP infrastructure: computer cabinets etc. Image transfer: 200 m fiber links between the Swedish building and the DSP housing. Heat release control: CPU and PSU heat storage in water for release at sunset and sunrise. This budget has no contingency at all, based on the expectation that computer hardware becomes cheaper rather than more expensive. The required matching comes from non-NWO sources of DOT funding. The request to NWO/EW amounts to k€ 141.

including solar physics teaching by the PI (who intends to spend multiple months per year on La Palma for this purpose). The students may come from astronomy, physics, computational physics or computer sciences, and will gain hands-on experience with state-of-the-art data acquisition and reduction techniques in international campaigns at the major astronomical observatory in Europe. Longer traineeships will also be possible, likely on EC funding. We regard this traineeship programme as an exciting and worthwhile education opportunity.

The emphasis in DOT scheduling will almost automatically lie on partnership in multi-telescope campaigns, since these have become the major and most productive observing mode in solar physics. Typically, wide-field DOT speckle tomography will be combined with SST adaptive-optics observing, spectropolarimetry with the other European telescopes on Tenerife, and space observation with SOHO, TRACE, and RHESSI[6].

Our longer-term strategy is to make the DOT an integral part of the upcoming Virtual Solar Observatory. In fact, DSP realization is the major step needed to merge the DOT into the VSO (see the *"White Paper on future DOT observing modes"* on the DOT website).

The DOT^{++} proposal to be submitted in NOVA-2 context for 2005–2010 (see pre-proposal on the DOT website) aims at a DOT aperture upgrade to 1.4 m providing $0.07''$ resolution (first +), and an overhaul of the speckle system including the DSP (second +). Its strategy is to maintain the DOT worldwide competitiveness also beyond 2006, when the 50-cm Solar-B telescope will start sharing the DOT's present niche 24 hours/day from space. The DOT field size will then become three times smaller (linearly in arcsec) due to the triple resolution, motivating replacement of the DOT imaging system with the much larger chip sizes then undoubtedly achieved in digital camera technology. That will also necessitate order-of-magnitude increase of the speckle pipeline with the much faster processing hardware which will then be available. Thus, we envisage 4–7 years DSP lifetime before overhaul.

7.6 Management and maintenance. Sütterlin will be DSP project manager. Bettonvil will be heat release system manager. Rutten is project leader, with a likely switch to the new UU solar physics professor at some time. DSP maintenance will be done while the crew is on-site. The greatest risk consists of disk failure, hence 2 spare disks in Table 1. The 5 modules including the 100 node processors do not contain any moving parts and should be highly reliable. The whole system will be on a UPS and hence be lightning-protected.

8 DSP budget

The total cost specified in Table 1 amounts to k€ 188, of which k€ 47 will be collected from non-NWO sources as matching contribution. The remaining amount requested from NWO/EW is k€ 141. The DSP housing will be covered from the regular DOT exploitation budget.

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[6] These are the currently operating space missions. From 2006 we may expect SDO and Solar-B, and likely a SMEX mission to be selected by NASA from two presently competing proposals – both with Utrecht participation because DOT co-observing is desired by both American consortia.

9 Literature.

The numbered references are the requested five relevant ones. They are available on the DOT website, with others.

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