Observing with a 21st Century Ground-Based Telescope - or How to do Unique Science with the Gemini Telescopes

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Observing with a 21st century ground-based telescope - or how to do unique science with the Gemini telescopes

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ABSTRACT

The new generation of ground-based telescopes offer unique observational opportunities for astronomy. By adopting the paradigm that observations must be matched to conditions it will be possible to use an 8m telescope to couple the spatial resolution of the Hubble Space Telescope with at least 10 times the collecting area. To effectively exploit these characteristics will require a considerable degree of pre-planning and prediction of environmental and atmospheric conditions combined with the ability to dynamically schedule observations. In this paper we describe the approach being taken by the Gemini telescopes to implement this new observing mode which is essential to realize Gemini's ambitious science requirements.

1. INTRODUCTION : THE CASE FOR QUEUE SCHEDULING

Spectacular images from the Hubble Space Telescope over the past several years have demonstrated the need for optical and infrared observations at sub-arcsecond spatial resolution in order to study and understand the physical processes occurring in resolved structures throughout the universe. Together with the direct increase in point source sensitivity with decreasing image size for a background noise limited telescope, this has led to the adoption of superb image quality as the key scientific requirement of the Gemini telescopes.

The distribution of natural seeing at the Gemini northern (Mauna Kea, Hawaii) and southern (Cerro Pachon, Chile) sites is superb with a median of 0.4 arcsec FWHM (Fig. 1). Nevertheless, the very best conditions, be they an image quality of better than 0.25 arcsec or a low IR background, will by definition always be rare. It will be one of the central challenges in scheduling and operating the Gemini 8m telescope to take full advantage of such conditions as and when they arise.

To facilitate the matching of observations to conditions, at least one half of the time on the Gemini telescopes will be operated in a so-called "queue-scheduled" mode. These observations will be pre-planned by the principal applicants and executed by Gemini staff astronomers according to well-defined criteria including matching required observing conditions, instrumental availability, program status and timeliness. The remainder of the time will be operated in the classical fashion with specific nights allocated in advance to particular projects, typically carried out by the applicant(s).

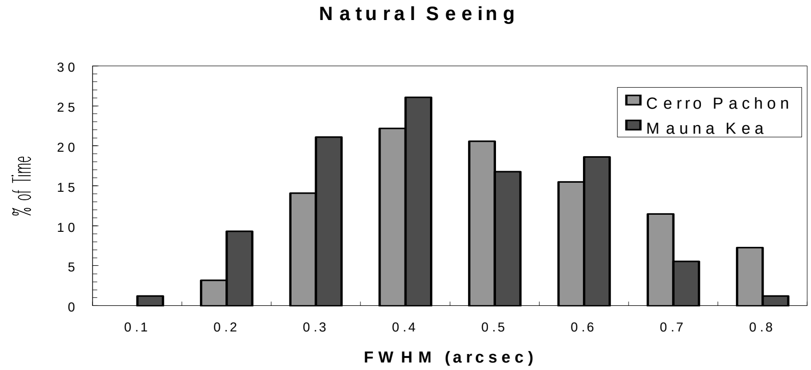

Figure 1 : distribution of natural seeing at Mauna Kea and Cerro Pachon.

In this paper we present an overview of the Gemini allocation and scheduling process with an emphasis on queue scheduling and simulations that have been carried out in order to demonstrate its fairness and efficiency. The goals of the process are described in section 2 and key features of the scheduling of classical and queue programs are given in sections 3 and 4, together with a worked example. The execution of queue-scheduled programs is discussed in section 5 and the philosophy of how the various types of time are distributed and charged amongst the partners is in section 6. Finally, section 7 describes the results from a number of simulations of the scheduling process.

2. GOALS OF THE ALLOCATION AND SCHEDULING PROCESS

The goals of the Gemini allocation and scheduling process are simply stated: fairness and efficiency. The former means that time must be divided fairly amongst the Gemini partners with each feeling that they have received an appropriate share of the “desirable” time. (The different types of time are discussed further in sections 6 and 7; note that time which is desirable for one partner might not be desired by others). It is expected that this balance will not be achieved accurately over one semester but only over two or three semesters (1-1.5yr). The second goal is that the allocation and scheduling process should permit partners to exploit the unique capabilities of the Gemini facility (e.g. image quality of IR background) but that the telescope should be used efficiently and never be sitting idle when it could be executing a program of interest to one of the partners. The success of this process should be measured in executing the maximum number of highly ranked scientific programs within these constraints.

3. SCHEDULING OF CLASSICAL PROGRAMS

Telescope proposals on Gemini will be solicited, reviewed and given a scientific priority independently by each of the Gemini partners. One important concept in bringing together these ranked lists of proposals, prior to scheduling both classical and queue time, is that of the “merging sequence”. The merging sequence, illustrated in Fig. 2, is a sequential list of the six Gemini partner countries as well as the host site (University of Hawaii or Chile). The frequency with which each partner occurs in the 43-entry sequence is roughly proportional to their involvement in the project and ensures approximately correct balance in access to the desirable time.

Each entry in the sequence corresponds to a specific amount of time. In the case of classical proposals this is nominally 0.5 nights, for queue proposals it is 4 hours. This nominal duration may be modified by the individual partners electing for a different classical/queue balance (e.g. Canada might choose for all of its time to be allocated in the queue mode in which case each entry in the classical merging sequence would fall to zero and in the queue sequence increase to 8 hours) or as a result of imbalances in the scheduling or usage of time in previous semesters.

1. US	11. UK	21. Brazil	31. US	41. US
2. UK	12. Canada	22. Argentina	32. Canada	42. UK
3. US	13. US	23. US	33. UK	43. US
4. Canada	14. US	24. UK	34. Chile	
5. Host	15. UK	25. US	35. US	
6. US	16. Host	26. Canada	36. US	
7. UK	17. US	27. US	37. UK	
8. US	18. Canada	28. Host	38. US	
9. US	19. US	29. UK	39. Host	
10. Chile	20. UK	30. US	40. Canada	

Figure 2 : the merging sequence of Gemini partners

The merging sequence describes the order in which proposals from the partners are selected. Classical programs are placed in the schedule in the quanta defined above; if a program cannot be scheduled it is skipped. Any minor advantage in being the partner with ‘first pick’ (the US in Fig. 2) is reduced by rotating the starting point amongst the partners in subsequent semesters e.g. the top-ranked UK classical program would be the first scheduled in the 2nd semester, the top Canadian program in the 3rd, and so forth.

4. HOW THE QUEUE IS ASSEMBLED

The queue is assembled from the individual partner ranked lists in much the same way as for the classical schedule described in section 3 using the merging sequence. In this case each entry is nominally equivalent to 4 hours of integration time but adjusted after the classical schedule is constructed. A simulation prevents overallocation of the semester by more than a certain fraction for any particular type of time compared with statistical expectations. This check prevents the queue being populated entirely by proposals requiring 20%-ile seeing with dark, photometric conditions, for example. The overallocation adopted as a baseline is 30% although this will be adjusted as a history of the variance in observing conditions is built up. Note that this overallocation means that although a program may be entered in the queue, it may not get to be executed. The queue will be erased at the end of each semester but individual partners may award “long-term” status to meritorious programs if desired, guaranteeing a position within that partners queue input to the next semesters merger. As in the classical case, programs which cannot be put into the queue because they exceed the overallocation are skipped. Once a program has been entered into the queue, the principal applicant will be contacted for the second phase of the application process which involves definition of the pre-planned observing and data reduction script(s).

4.1 A worked example

A worked example showing the first 4 steps in the construction of the queue is shown in Figs. 3 and 4. The first frame (queue step 1) shows the separate national lists ranked in order of scientific priority and the merging sequence with the first entry (US) highlighted. In this example, the top-ranked US program has requested 8 hrs of time, the first 4 of which (corresponding to one entry in the merging sequence) have been loaded into the merged queue. At step 2, the top-ranked proposal from the next entry in the merging sequence (UK) has been selected and the corresponding 4 hrs loaded into the queue. At step 3 the next 4 hrs corresponding to the 3rd entry (US) in the sequence is used to complete the loading of program US1 which is then crossed off the national ranked program lists. In step 4 the first 3 hrs corresponding to the Canadian sequence entry are use to complete program Ca1 and 1 hr of Ca2 is loaded into the queue. This process continues until all of the time has been allocated.

Queue Step 1

Merged Queue

US1 (4hr)

merging sequence

1. US
2. UK
3. US
4. Canada
5. Host
6. US
7. UK
8. US
9. US
10. Chile
11. UK
12. Canada
13. US
14. US
15. UK
16. Host
17. US
18. Canada
19. US
20. UK
21. Brazil
22. Argentina
23. US
24. UK
25. US
26. Canada
27. US
28. Host
29. UK
30. US
31. US
32. Canada
33. UK
34. Chile
35. US
36. US
37. UK
38. US
39. Host
40. Canada
41. US
42. UK
43. US

ranked program lists

US	UK	Canada	Chile	Brazil	Argentina	Host
US1 8 hrs	UK1 24 hrs	Ca1 3 hrs	Ch1 10 hrs	Br1 10 hrs	Ar1 20 hrs	
US2 35 hrs	UK2 40 hrs	Ca2 10 hrs	Ch2 7 hrs	Br2 6 hrs		
US3 6 hrs	UK3 5 hrs	Ca3 16 hrs	Ch3 24 hrs			
US4 10 hrs	UK4 10 hrs	Ca4 36 hrs	Ch4 5 hrs			

Queue Step 2

Merged Queue

US1 (4hr)
UK1 (4hr)

merging sequence

1. US
2. UK
3. US
4. Canada
5. Host
6. US
7. UK
8. US
9. US
10. Chile
11. UK
12. Canada
13. US
14. US
15. UK
16. Host
17. US
18. Canada
19. US
20. UK
21. Brazil
22. Argentina
23. US
24. UK
25. US
26. Canada
27. US
28. Host
29. UK
30. US
31. US
32. Canada
33. UK
34. Chile
35. US
36. US
37. UK
38. US
39. Host
40. Canada
41. US
42. UK
43. US

ranked program lists

US	UK	Canada	Chile	Brazil	Argentina	Host
US1 8 hrs	**UK1 24 hrs**	Ca1 3 hrs	Ch1 10 hrs	Br1 10 hrs	Ar1 20 hrs	
US2 35 hrs	UK2 40 hrs	Ca2 10 hrs	Ch2 7 hrs	Br2 6 hrs		
US3 6 hrs	UK3 5 hrs	Ca3 16 hrs	Ch3 24 hrs			
US4 10 hrs	UK4 10 hrs	Ca4 36 hrs	Ch4 5 hrs			

Figure 3 : the first 4 steps in assembling the queue.

Queue Step 3

Merged Queue

US1 (8hr)
UK1 (4hr)

1. US
2. UK
3. US
4. Canada
5. Host
6. US
7. UK
8. US
9. US
10. Chile
11. UK
12. Canada
13. US
14. US
15. UK
16. Host
17. US
18. Canada
19. US
20. UK
21. Brazil
22. Argentina
23. US
24. UK
25. US
26. Canada
27. US
28. Host
29. UK
30. US
31. US
32. Canada
33. UK
34. Chile
35. US
36. US
37. UK
38. US
39. Host
40. Canada
41. US
42. UK
43. US

merging sequence

ranked program lists

US	UK	Canada	Chile	Brazil	Argentina	Host
~~US1 8 hrs~~	**UK1 24 hrs**	Ca1 3 hrs	Ch1 10 hrs	Br1 10 hrs	Ar1 20 hrs	
US2 35 hrs	UK2 40 hrs	Ca2 10 hrs	Ch2 7 hrs	Br2 6 hrs		
US3 6 hrs	UK3 5 hrs	Ca3 16 hrs	Ch3 24 hrs			
US4 10 hrs	UK4 10 hrs	Ca4 36 hrs	Ch4 5 hrs			

Queue Step 4

Merged Queue

US1 (8hr)
UK1 (4hr)
Ca 1 (3hr)
Ca2 (1hr)

1. US
2. UK
3. US
4. Canada
5. Host
6. US
7. UK
8. US
9. US
10. Chile
11. UK
12. Canada
13. US
14. US
15. UK
16. Host
17. US
18. Canada
19. US
20. UK
21. Brazil
22. Argentina
23. US
24. UK
25. US
26. Canada
27. US
28. Host
29. UK
30. US
31. US
32. Canada
33. UK
34. Chile
35. US
36. US
37. UK
38. US
39. Host
40. Canada
41. US
42. UK
43. US

merging sequence

ranked program lists

US	UK	Canada	Chile	Brazil	Argentina	Host
~~US1 8 hrs~~	**UK1 24 hrs**	~~Ca1 3 hrs~~	Ch1 10 hrs	Br1 10 hrs	Ar1 20 hrs	
US2 35 hrs	UK2 40 hrs	**Ca2 10 hrs**	Ch2 7 hrs	Br2 6 hrs		
US3 6 hrs	UK3 5 hrs	Ca3 16 hrs	Ch3 24 hrs			
US4 10 hrs	UK4 10 hrs	Ca4 36 hrs	Ch4 5 hrs			

Figure 3 (contd.)

bright - photometric

IR background

image quality

	≤0.2	≤0.5	U
≤0.2	(4h)	(6h)	**4 of (10hr)**
≤0.5	(6h)	(9h)	(15h)
U	(9h)	(15h)	(25h)

bright - spectroscopic

	≤0.2	≤0.5	U
≤0.2	(4h)	(6h)	(10hr)
≤0.5	(6h)	(9h)	(15h)
U	(9h)	(15h)	(25h)

dark - photometric

	≤0.2	≤0.5	U
≤0.2	(4h)	(6h)	(10hr)
≤0.5	(6h)	(9h)	(15h)
U	(9h)	(15h)	(25h)

dark - spectroscopic

	≤0.2	≤0.5	U
≤0.2	(4h)	(6h)	(10hr)
≤0.5	(6h)	(9h)	(15h)
U	(9h)	(15h)	(25h)

Figure 4 : checking availability of observing conditions at queue step 1.

At each step in the queue assembly the requested observing conditions are tested against those available based on a statistical expectation for the semester. Fig. 4 shows an example of the time available (with a 30% overallocation) for a 2 month period in the semester and divided amongst dark, bright, photometric and spectroscopic time with three quality bands of IR background and image quality (20%-ile, 50%-ile and unconstrained). In the example, program US1 has requested bright, photometric conditions with the best image quality but no constraint on IR background (it is a near-IR H-band imaging experiment, say). Of the 10 hrs expected to be available, 4 hrs have been 'assigned' to this program. If the request had exceeded the time available, and if no time under better conditions (e.g. 50%-ile IR background) were left, then the program would have been skipped and not entered into the queue. It is sobering to note how little of the very best quality time is likely to be available (only 4 hr of 20%-ile image quality, IR background, dark, photometric time in this example 2 month period !).

5. EXECUTION OF QUEUE OBSERVATIONS

As described in section 4, the queue is loaded on the basis of scientific rank and nationality, thus determining *whether* a program is likely to be executed. The specific requirements of an observation such as image quality, lunar phase, hour angle, program status, instrumentation etc., should determine *when* an observation is executed. The goal of the execution process is that, at the end of the semester, all of the programs in the queue above a line (near the bottom) will have been completed and none below it started.

In practice there are a number of ways in which we can draw observation from the queue. First let us sub-divide the queue into bands of equal scientific quality containing some number of proposals and match the observations to the current conditions. Fig. 5 shows the first 15 entries in the merged queue. Only those with light backgrounds (UK1, Ca1 etc.) have requirements consistent with the conditions.

In the extreme example that the length of a scientific band is only one proposal, then the execution would proceed from the top of the list down and there would be limited optimisation and matching to the conditions. In the other extreme of the length of a band being the entire queue then although there would be excellent matching to conditions, the scientific quality ranking from the national partners would have been ignored.

	Program	Weighting Function
Scientific Band 1	US1	5.3
	UK1	12.1
	Ca1	6.1
	Ho1	15
	US2	2.5
	Ch1	8.2
	US3	12.1
Scientific Band 2	UK2	3.3
	Br1	7.7
	Ar1	4.5
	Ca2	35.1
	US4	5.5
	Ho2	9.1
	UK3	4
	US5	12.3

Figure 5 : the top of the queue during execution

To preserve the scientific ranking whilst ensuring that observations are executed under appropriate conditions a weighting function has been adopted. For each program whose requirements match the conditions, a weighting function is computed from parameters including the fraction of time remaining in the semester, the hour angle, and the program status (i.e. whether observations from the program have already been executed). Then within the highest scientific quality band the observation with the largest weight is selected for execution (UK1 in the example in Fig. 5). If two observations have the same weight then that which is closest to the top is chosen. If no program in the top band can be executed because better conditions are required, then the search for a suitable program proceeds to the next band down.

The choice of the optimum band length and the full list of parameters in the weighting function are yet to be determined and will result from a simulation of the queue execution.

6. HOW TIME IS TO BE CHARGED

The intent in counting usage of Gemini telescope time is for parity between queue and classically scheduled time. Therefore classical time will be charged as hours allocated, starting and ending at astronomical twilight for nighttime observing. Classical observers will be encouraged to obtain the nominal calibration exposures in order to ensure the long term usefulness of the data archive.

Queue time will be charged as hours used. The clock for a queue exposure begins at the start of the slew for that observation; thus the time to slew to the object, acquire it, configure the instrument and the telescope, read out the detector and confirm that the data are satisfactory are all charged. The nominal calibrations will be provided (with charges split among all those programs which can use a given calibration) to queue scheduled programs. Any additional calibrations required for a queue scheduled program will be explicitly charged to that program.

The Gemini queue observer will have some discretion over the integration time for a given observation. Proposers will have to give an estimated integration time for the nominal conditions they require, but if an observation is done under better conditions, it would be inefficient (and not what a classical observer would do) to insist on the same integration time. Therefore, proposers will be asked to submit criteria for establishing that an observation has been successfully completed. During the early use of the facility when the instrument and telescope characteristics are still being refined, this criteria might simply be integration time, but it is expected to evolve into a signal-to-noise ratio criterion. Then if the criterion is achieved in less than the nominal time (approved by the time allocation committee), the observation is terminated early. If the integration time must be increased - up to 20%, say - to achieve success, it will be increased. If the criterion for success requires an increased integration time of more than 20%, it will be judged that the prediction is in error and the program will be bounced back to the proposer and the allocation committee for guidance on how to proceed.

At intervals throughout the semester, the time accounting will be reviewed. Imbalances in the usage of time (calculated relative to the nominal availability and normalized by the total usage amongst the partners) may be used as a feedback by adjusting the weighting factors determining queue execution and by adjusting the duration of each partners merging sequence entry prior to the time allocation and scheduling meeting.

7. SCHEDULING SIMULATIONS

To study the scheduling process in more detail and understand the potential areas of difficulty, a (manual) simulation of both classical and queue scheduling (but not, yet, queue execution) has been carried out.

7.1 Input to the simulations

As input to this exercise, lists of dummy proposals simulating the output from the national time allocation committees were produced by the Gemini project scientist team and national project scientists (the latter incorporating any national biases in instrument or observing condition usage). A total of 41 classical and 78 queue proposals distributed amongst observing conditions and instruments was produced. Scientific priority rankings were assigned at random. Relevant information for the queue applications, supplementary to the instrument (choice of 4), target list and schedule timing (dark/bright; acceptable dates) required for a classical proposal, were the image quality (specified as better than 20%-ile, better than 50%-ile or unconstrained), IR background (same three categories as image quality) and cloud cover (photometric or spectroscopic).

In addition a blocked out schedule giving an example of the likely distribution of classical, queue and Directors/engineering time, instrument availability and lunar phase was produced. (In practice this would be provided ahead of the Gemini call for proposals for potential proposers to assess the availability of facilities as well as for Gemini staff planning). As an illustration of the level of realism incorporated, the classical and queue periods are both scheduled in 5 nominal 18 night blocks, interleaved with 3 nights Directors/engineering time for instrument and facility checks, with both dark and bright time accessible, but out of phase, to each classical/queue period. Time for instrument changeovers is included (three of the four nominally available instruments can be mounted at any one time on the Cassegrain instrument support structure).

7.2 Classical scheduling results and conclusions

Scheduling of the classical time was exceedingly straightforward and, with hindsight, it is easy to see why this might be the case. Unlike the usual case of scheduling an entire semester, only about one half of the semester was being classically scheduled which together with the division of this time amongst 5 blocks (with boundaries which were permitted to move by plus or minus a few nights) and the availability of three instruments led to a great deal of flexibility in the allocation process. The results are presented in Fig. 6, showing the nominal allocation in nights, the number of nights requested and the actual allocations. It can be seen that the latter are in excellent agreement with the nominal allocations (or request, if smaller).

Examining the success of the exercise in terms of scientific ranking, the schedule contains all of the top-ranked classical proposals from the UK, Canada and University of Hawaii, filling their nominal allocations within the requested constraints. For the US proposals, those ranked 1-13 and 15-16 were scheduled, only the 14th ranked proposal could not be.

	nominal alloc.	request	actual alloc.	fraction of total alloc.
US	**37**	55	**36.5**	48%
UK	**16.5**	21	**16.5**	22%
Canada	10	**7.5**	**7.5**	10%
UH (host)	7.5	**15.5**	**15.5**	20%
Chile	3.5	**0**	**0**	0%
Argentina	1.5	**0**	**0**	0%
Brazil	1.5	**0**	**0**	0%
sum	77.5		76	
Notes :				
(1) UH requested all time to be classical				
(2) Canada requested more queue than classical				
(3) Ch., Arg., Bra., requested all queue				

Figure 6: results of the classical scheduling simulation

7.3 Queue scheduling results and conclusions

The queue scheduling simulation was necessarily more elaborate as it involved accounting for time usage in each category of observing conditions at each step. Two independent trials were executed. In the first, programs were loaded into the queue in their entirety as opposed to the loading in nominal 4 hr quanta described in section 4 and employed for the second trial. Early in the first trial (when selecting the, randomly, top-ranked Canadian application which requested all of the best image quality, dark, photometric time) it became clear that the loading of any program which requested a large fraction of the available time in any observing condition category could significantly skew the distribution of desirable time amongst the partners. Although this imbalance could readily be corrected in subsequent semesters, when the others partners occur first in the merging sequence, it is clearly unattractive to require such major corrections. The second trial was much more successful in achieving a fairer balance of access to the desirable observing conditions amongst the partners as shown in Figs. 7-10.

Figs. 7 and 8 summarize the queue scheduling results analyzed in terms of the observing conditions, subdivided into the best conditions (the sum of time allocated in 20%-ile image quality or IR background), average conditions (likewise for 50%-ile conditions) and the total allocations. The top-left box shows the nominal queue allocations (after adjustment for the classical scheduling results) in hours and their distribution amongst the partners. For each of the three observing condition categories the other boxes show for each partner the actual ‘allocation’ (i.e. program time loaded into the queue), the request, the allocation as a fraction of the request, the allocation as a fraction of the total over all partners and the actual allocation as a fraction of the nominal allocation. (Note that the total queue allocation was only about 75% of that available due to the input proposals undersubscribing the poorest conditions). Comparison of the two figures indicates that the second trial was fairer with the distribution of time amongst the partners (e.g. fraction of total allocation) showing much less variance from the nominal allocations.

The queue scheduling results were also analyzed in terms of the distribution of time amongst the partners for their top-quarter and top-half ranked proposals. Figs 9 and 10 show for each partner the number of proposals in these categories, the request, and the allocation resulting from the two trials. Bearing in mind that the small number of proposals from the smaller partners can influence the statistics in this analysis, the second trial succeeds significantly better than the first in ensuring that the top ranked proposals are ‘allocated’ despite the method of loading proposals into the queue in nominal 4 hr quanta rather than in their entirety.

nominal queue availability (adjusted for classical schedule)		
	hrs	frac.
US	392	**47%**
UK	173	**21%**
Ca	130	**16%**
Ch	70	**8%**
Ar	35	**4%**
Br	35	**4%**
sum	835	

total queue time (sum of all conditions)						
	alloc	request	frac. of request	frac. of total alloc	frac. of nom. avail.	frac. wrt nominal
US	319.6	445	72%	**52%**	82%	112%
UK	120.1	217	55%	**20%**	69%	95%
Ca	75.2	247	30%	**12%**	58%	79%
Ch	48.3	80	60%	**8%**	69%	95%
Ar	30	40	75%	**5%**	86%	118%
Br	15.7	40	39%	**3%**	45%	62%
sum	608.9	1069			**73%**	

average conditions (sum of avg im. and avg IR)					
	alloc	request	frac. of request	frac. of total alloc	frac. wrt nominal
US	178.7	183.5	97%	**46%**	98%
UK	95.1	126	75%	**24%**	118%
Ca	58.2	180	32%	**15%**	96%
Ch	21.3	25	85%	**5%**	65%
Ar	30	30	100%	**8%**	184%
Br	5	20	25%	**1%**	31%
sum	388.3	564.5			

best conditions (sum of best im. and best IR)					
	alloc.	request	frac. of request	frac. of total alloc	frac. wrt nominal
US	39.9	114.5	35%	**33%**	69%
UK	43.2	84	51%	**35%**	170%
Ca	31.5	67	47%	**26%**	165%
Ch	3.3	30	11%	**3%**	32%
Ar	4	10	40%	**3%**	78%
Br	0.7	25	3%	**1%**	14%
sum	122.6	330.5			

Figure 7 : results of the 1st queue scheduling trial

nominal queue availability (adjusted for classical schedule)		
	hrs	frac.
US	392	**47%**
UK	173	**21%**
Ca	130	**16%**
Ch	70	**8%**
Ar	35	**4%**
Br	35	**4%**
sum	835	

total queue time (sum of all conditions)						
	alloc	request	frac. of request	frac. of total alloc	frac. of nom. avail.	frac wrt nominal
US	334.2	445	75%	**51%**	85%	109%
UK	146	217	67%	**22%**	84%	108%
Ca	70.9	247	29%	**11%**	55%	70%
Ch	49	80	61%	**8%**	70%	90%
Ar	26	40	65%	**4%**	74%	95%
Br	25	40	63%	**4%**	71%	92%
sum	651.1	1069			**78%**	

average conditions (sum of avg im. and avg IR)					
	alloc	request	frac. of request	frac. of total alloc	frac wrt nominal
US	183.9	183.5	100%	**52%**	111%
UK	73.7	126	58%	**21%**	101%
Ca	35.8	180	20%	**10%**	65%
Ch	30	25	120%	**8%**	101%
Ar	24	30	80%	**7%**	162%
Br	6	20	30%	**2%**	41%
sum	353.4	564.5			

best conditions (sum of best im. and best IR)					
	alloc.	request	frac. of request	frac. of total alloc	frac wrt nominal
US	110.3	114.5	96%	**42%**	90%
UK	70.6	84	84%	**27%**	130%
Ca	56.9	67	85%	**22%**	140%
Ch	9	30	30%	**3%**	41%
Ar	4.9	10	49%	**2%**	45%
Br	10	25	40%	**4%**	91%
sum	261.7	330.5			

Figure 8 : results of the 2nd queue scheduling trial

	no. of props.	request (hrs)	1st trial alloc.	1st trial fraction alloc.	2nd trial alloc.	2nd trial fraction alloc.
US	8	105	86.9	**83%**	105	**100%**
UK	6	84	64.4	**77%**	77	**92%**
Ca	2	36	28.2	**78%**	27	**75%**
Ch	2	30	20	**67%**	24	**80%**
Ar	1	20	20	**100%**	16	**80%**
Br	1	10	0	**0%**	10	**100%**

Figure 9 : queue scheduling results for the top-ranked quarter of proposals

	no. of props.	request (hrs)	1st trial alloc.	1st trial fraction alloc.	2nd trial alloc.	2nd trial fraction alloc.
US	17	203.5	151	**74%**	179.5	**88%**
UK	12	146	113.7	**78%**	131	**90%**
Ca	4	91	64.2	**71%**	64.9	**71%**
Ch	3	40	20	**50%**	24	**60%**
Ar	2	30	20	**67%**	16	**53%**
Br	2	15	5	**33%**	15	**100%**

Figure 10 : queue scheduling results for the top-ranked half of proposals

7.4 Overall simulation conclusions

From both the classical and queue scheduling simulations it can be seen that the use of the merging sequence with its inherent balanced distribution to allocate time on the Gemini telescopes results in the partners having fair and equal access to the desirable observing conditions. Although a simulation of the queue execution has yet to be carried out, the loading of the queue using a statistical distribution of the expected observing conditions suggests that this too will be successful and further, through the possibility of adjustment to the weighting function to correct minor imbalances in the time actually charged, will result in fair usage of these conditions.

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