

DISCUSSIONS

As indicated in the opening remarks, a significant portion of JD1 consisted of round table and general discussions. These were tape recorded and a transcription of the participants' remarks follows. These remarks were lightly edited to an extent necessary to help ensure clarity and brevity. No substantive omissions occurred due to either editing or tape quality. Regarding the latter, the editor wishes to thank the LOC for the excellent recording facilities and the associated, most helpful technicians. The final responsibility for the transcription is, of course, the editor's.

The six members of the panel taking part in the round table discussion were: B.R. Guinot, J.A. Hughes, H. Jenkner, K. Johnston, J. Kovalevsky and C.A. Murray.

Hughes: In order to get things started, I would like to point out some of the possible difficulties – that is to say, there is not much doubt that the extra-galactic based reference system is the promise of the future – I think there is very little doubt of that. But of course, the primary problem as I see it, being a practical fellow, is the operational realization of such a system in such a way that it could be used by, so to speak, the astronomer in the street. If given a telescope, what does one do with the wonderful quasi-inertial qualities of these objects? If you think about it, in the case of the classical system, we really didn't have quite the same problem, because after all, when one does a fundamental or absolute program one doesn't point a transit circle at the equinox and say, "there it is!", it is defined implicitly in the observation of the stars. One does azimuths and levels, et cetera; and measures clock stars, and most importantly, measures the solar system objects, and by applying the presumed laws of physics which govern their motion we then are able to subtract out that sort of motion and end up with what we call inertial coordinates. But in that process, the zero point is inherent in the positions of the stars; I've often said when you say this star has a right ascension of x hours you are not saying the star is x hours from the equinox, you are saying the equinox is minus x hours from the star. In effect we have thousands of bright, accessible "equinoxes" all over the sky. That might be a very obvious thing, but I think it sort of pinpoints one of our operational difficulties; how do we transform that sort of thing into the faint extra-galactic kind of reference system, leaving aside for the moment, any questions of how we define any zero points, particularly in right ascension. So, having said that, I've gone out on a small limb – does anybody care to respond to that in any way?

Murray: I would like to support the point that the reference frame must be accessible to observers – I think that's the point that Jim has made, that it's all very well to have theoretical definitions, but in practice you have actually got to go to a point in the sky and say that star is so far away from that star, and I know that star is so far away from the equinox, therefore, I can get the position of the target object. I think that is the important thing to remember. That is why it is important to include in your reference frames a sufficient number of objects in your practical frame. I am not saying in your fundamental definition of the frame, but in your practical presentation of the frame, to the outside world, sufficient objects at sufficiently faint magnitudes to satisfy the needs of astronomers in all fields who wish to identify objects and study their motions.

Guinot: I don't see why it would be so different from what is already done right now – the only difference is that you will have a primary reference which in fact will be used to refer your secondary reference to, which are the star catalogs, but it will not change anything – you will have star catalogs with the same stars, with the same number of stars, but the positions will be referred to the extra-galactic sources.

Kovalevsky: I think the situation is certainly almost the same except that presently where we are using a dynamical system, we have to go back to what is called fundamental observations which are either observations of the Sun or of some planets. Now with the new idea of having the extra-galactic systems as the fundamental one, we come to a completely new kind of fundamental observations which will be again those which refer now, not to the Sun or the planets or stars, but which refer the stars to the extra-galactic objects. I think all the efforts which shall be made now, and of which we have heard some already, to relate extra-galactic objects to stars, will become, I think, the most important part of astrometry – the equivalent of the present so-called fundamental observations in the future. So I think the more we can find radio stars, the more ways we can link some stars to galaxies, the more new ways of having this new type of fundamental observation we are going to construct.

Hughes: It appears that we are going to find a greater dichotomy between people interested in positions of stars, say, and people interested in proper motions, the latter community, of course, being much larger. There, if one has inertial points, so to speak, all over the sky, one could determine inertial proper motions without any consideration of large angle measurements – I believe that was mentioned earlier today. I think it is a very important point, because if you are not interested in positions, I think the problem is somewhat lessened.

Murray: I agree, of course that the ideal is to have your reference frame defined by extra-galactic objects, but at the present time there are simply not enough of these things to provide a proper reference frame which is practically accessible; so therefore one has to have interpolation from stars, and it's the link between stars which we can all observe, and relatively few extra-galactic sources, indeed very few, speaking in relation to the density of stars in the sky. We must really concentrate on the linking of the extra-galactic frame, which at best may be just a zero point calibration. It's the stars we must concentrate on. I think here I would like to raise a flag for something I'm rather keen on, and that is, extending the fundamental reference frame, and now I am using the word "fundamental" in the sense that it's already always been used, that is, observations relative to a dynamical system defined in connection with the solar system, to much fainter stars. We now have an opportunity with transit circles such as the Carlsberg on La Palma, to observe several magnitudes fainter than has been possible in the past, on a routine basis. I would like to suggest that we somehow decide on setting up a reference frame, for the sake of argument, say to visual magnitude 12 or 12 1/2 which is perfectly accessible to the Carlsberg, and presumably to other automatic meridian circles, which will obviate a lot of the difficulties that we have been having over the last ten or fifteen years in this linking of stars to what we now recognize as fundamental zero points, the extra-galactic objects.

Hughes: I might remark in that context that Dr. Requieme from Bordeaux will be giving a paper in one of the Commission 8 meetings on that very subject later this week. I believe Ken Johnston has something to say.

Johnston: I guess I'm coming from a different point of view; I think the fundamental reference frame should be based on quasars, and I think you'll agree with that, and I would say that it is the fundamental reference frame, and I think Ivan Mueller would agree with this too, and that perhaps as few as 100 objects may be enough. If one could measure the angles between those 100 objects extremely accurately, say to a fraction of a milliarcsecond, and if that's the accuracy you're interested in, that would be a good enough reference frame. When one wants to go beyond accuracies like that, say, to a tenth of a milliarcsecond, then you are going to have to consider a whole different kind of object. But I would say that the reference frames are really defined by the objects you want to look at. In looking at stars I would like to have some star reference frames that were related to a quasar reference frame which I think is fundamental. Then you are always stuck with the fundamental fact that you are making all these observations from the Earth, unless you're in space. If you're making them from the Earth, then you have to have some reference frame which is going to be a reasonable reference frame to use from the platform that you are observing from.

Hughes: I agree with that Ken, there is no question about it, but consider a particular case; for example, someone has a star which they are pretty sure is going to be occulted by a minor planet next week. Now I have these 100 magnificent inertial objects and I'm asking how do we transfer those admittedly superb qualities, how to transfer that now to the problem in hand. That I think can be done, but it is going to require an awful lot of work. That's the point, I think.

Jenkner: I would like to underline the accessibility argument or realization argument once more. I think it is very important, as you said, that we have say, 100 highly precise objects, but the next step down should already be a stellar reference frame of also very high accuracy, with sufficient numbers to have at least one to say five or six objects per square degree accessible directly to the observer. We can see that problem right now in our work on the Guide Star Catalog where the relative positions are fairly good for the kind of work, or kind of instrumentation they are using, but where the absolute accuracy lags behind considerably, mostly because we are forced to use such things as the SAO and AGK3 catalog as our "reference catalog," which they were never intended to be. So what is clearly lacking is something of the quality of a real fundamental catalog which would allow us to use really fundamental positions to avoid the errors.

Murray: I think we all are agreed so to speak with the philosophy angle; we agreed that the external extra-galactic objects provide a fine reference frame; we're all agreed that we need interpolation objects. What we ought to be discussing I believe at the IAU is the steps to be taken in order to realize this. Thirty years ago, as I said earlier on this afternoon, there was the planning for the AGK3, AGK3R program; this was essentially an IAU based program and worked very well, and from that you got the AGK3 which now of course is running off but at the epoch of 1961 it was jolly good. And similarly we had the SRS - this again was an IAU

based program. To my mind, the IAU, this place, is the place where we ought to be discussing the practical problem of planning the programs, executing the programs – we're agreed we want a reference frame, we're agreed we want lots of stars in the reference frame. We have got at the present time a moderately good reference frame. We are doing our best to improve the southern hemisphere, but it's up to this generation, I think, from now on to consider extending that reference frame for the next 20 years or so, and I think we ought to be seriously considering re-photography, new observing of reference stars on the fundamental basis, and it is here I am suggesting that we should have a new fundamental system of faint stars directly to tie the interpolation stars to. I think we're at the time when we can start thinking about making a break with the past and actually constructing a new observational reference frame with properly planned programs with the new instrumentation that we've got.

Kovalevsky: I'm sorry, I think I have heard several times, the word "fundamental," I think we shouldn't use this all the time, I think if we really come to the idea of what we agreed upon, of the extra-galactic frame, the only fundamental observation will be the VLBI observations, all the rest will be something to link and even HIPPARCOS is no more fundamental. I think we could take, for instance, an example of what is being done in geodesy; the first order points will be these extra-galactic objects, the quasars – second order will be, I hope, HIPPARCOS, but again, we should be careful because we still have a few chances that something fails in HIPPARCOS – and what we shall do then will be difficult. That's why I would say, do not stop anything from Earth-ground observations in astrometry before you are sure that HIPPARCOS is going to give some results. And then, I think you have a third order, and the third order net is the one we are speaking of, that Andrew mentioned, and which will probably be something of the same kind of – maybe a little different – maybe a million stars of magnitude 11-13 and I should say that at sometime you will need another one of magnitude 16-17 for much smaller fields or for observations of much fainter stars. So I think we can really plan now.

Murray: I agree again that the extra-galactic objects provide the fundamental reference frame; I would prefer to call it absolute, because the word fundamental has strong connotations in the context in which we are speaking. But that's no good for producing a differential catalog with a transit circle. Apart from the fact that you can't observe these things with a transit circle, there aren't enough of them; I think we've got to attack the problem from both ends and then make the ends meet in the middle somewhere. You've got to still have a dynamically coherent reference frame for use with optical observations from the ground. We still have that even when HIPPARCOS has gone up, we still have got to have the fainter stars interpolating between the HIPPARCOS stars, and after all, as Jean says, the HIPPARCOS hasn't actually gone up yet; and we must bear in mind the possibility there might be some disaster, you never know, and so we ought to consider continuing with the present procedure which I would say is starting at both ends with the observations

with meridian instruments on a dynamically defined frame where you've got enough fundamental stars, in the sense of the word as we are used to using it in connection with fundamental observations with meridian instruments. I don't think you can throw that away - you can't just tie things directly to the extra-galactic frame.

Hughes: May I comment on that. There is even another consideration and that is the observation of the solar system dynamics as an end in itself. This is a very important thing to do and so this will continue in any event. But let me give you a possible scenario to address your previous question. Consider, that we have HIPPARCOS, let us assume it works, we have no disasters, well now we have a magnificent reference star system, now we use this with an astrophotometer, and now we suddenly have extended, we have filled in a vast gap here, and now we have the possibility of a quasar-based system of stars covering perhaps from 7th magnitude to as faint as you can go with your wide-field instrument. That's for starters, but I quite agree with Andrew Murray that the opposite end, the planetary system, must at the same time be observed. I believe Ken Johnston wanted to say something at this point.

(NB With the acquiescence of the chairman, K. Johnston requested that I. Mueller speak at this point although the latter was not a panel member. The round table discussion was formally ended a bit later, but several non-panelists made welcome contributions from this point on.)

Mueller: I would just like to make a comment from a somewhat different point of view on the subject. I agree with everything that everybody has said - that it is important that whatever system you have should have accessibility, et cetera, however, one, I think, should not lose sight of the fact that these reference frames as materialized by whatever system we are discussing, like the extra-galactic sources, or stars, or whatever, will be used by someone. And the user community, or maybe I should say the technology the user community is using nowadays, at least in the last ten or fifteen years, has been developing so fast, that those, let's call them fundamental reference frames, which take 15-20-30 years to establish, have very little use because by the time they become available to users in the form of a catalog or ephemerides or whatever, they are almost by definition obsolete, and you have to start all over again to get to the next system. I hate to say this, but the FK5 is one of these systems. I'm not saying that it is in fact obsolete but we just heard that it was started in 1973 - it is now 1985, now it has been 12 years and it will be another year, 13 years in all, before it actually will come out and become useful for someone who wants to put his system on the FK5. The FK4 which is still officially adopted for the time services, for example, now is considered by everybody to be obsolete. Now even from this point of view, these extra-galactic systems have a great advantage, namely that you can add sources to the catalog as you go with your observations and you don't have to rely on any other type of observation but observations of these sources. So this is another advantage of, let's say pulling in that direction, and if we do go in the other direction, then I suggest that we have to facilitate, somehow, the methods which are available to

set up other kinds of systems so that they can be made available in a shorter period of time.

Johnston: I would like to make one point here – everyone is referring to the quasar reference system as fundamental, but the quasar reference system we believe will probably ultimately give us maybe a tenth of a milliarcsecond accuracy measuring over large arcs in the sky. There may be some other system or other method of observation, or some other objects that may give us something better than that in the future, so we should be very careful in what we're defining and in the terms that we use here. The systems that we are attempting to use, as Dr. Mueller points out, it's what do we really want to do with them – the problem with the quasar reference frames, as he correctly says right now, is that we don't know many of the constants when we try to use these angles that we measure between the quasars, when we are trying to express them in terms of the reference frames that are forced upon us today – it makes it difficult to publish papers – we don't know what the numbers are – it's very, very difficult I think. What we want to do is to go to some reference frame that allows flexibility when one can achieve the highest accuracy. I don't know how to do that though.

Hughes: Any comments on that.

Fliegel: I wonder how the panel would react to the idea of working pulsar observations into your scheme also, on the grounds that as far as I know the Earth's orbit is best defined now by observations of VIKING, by non-traditional techniques involving interplanetary spacecraft, and very well defined indeed, but, of course, that does not give you a system with respect to the stars. And you have all been pointing out that the quasars do not tell you anything with respect to the Earth's orbit, but pulsars might serve as the missing link between the two. No? Because if you have a good program of observing pulsars, the Earth's orbit is very accurately reflected in those measurements.

Johnston: I think you have a very good point there Henry – but pulsars have notoriously high proper motions, and this problem is going to come back to haunt us all – the problem of the stars and their proper motions.

Fliegel: May I respond to that? I grant you that the pulsars have proper motions, but that has never stopped traditional stellar astronomy in the past, and my point is only that by working in a complete program of pulsar observations can you determine the Earth's orbit with respect to a stellar frame, and that seems to be the very technique that you are looking for. I am not saying that pulsars could replace quasars – that's not my point at all.

Murray: I quite agree with you – I thought we were going to have a paper about that this morning but it never came. (NB Reference is made to a paper by J.C. Backer which was on the program and which was not withdrawn. The author, however, did not appear at the JD.) I think the idea of using pulsars to relate the radio frame to the dynamical frame of the solar

system is fine; I would like to ask a question – if I may, what accuracy can we get for the position of a pulsar in the ecliptic frame from the timings?

Johnston: I think the present accuracies are believed to be on the order of a 100th of an arcsecond, but the discrepancies between the measurements made by one technique versus the direct angle measurements made with interferometers are on the order of a few tenths of an arcsecond right now. And those discrepancies have to be resolved.

Murray: But those discrepancies are precisely the things we are looking for.

Hughes: Speaking of discrepancies, let me bring up another point – we all hear about this, and maybe we sweep it under the rug or maybe it does not have to be swept under the rug – that's the question of things like evolution of structure, structure varying with wavelength, et cetera, all those phony proper motion type things we hear about. Of course, this ultimately will be some sort of limit on the extra-galactic frame – there is no question about that. Ken, would you care to comment on this particular aspect of this whole question?

Johnston: That was why I was limiting the accuracy to what I felt one could get from an extra-galactic frame to about a tenth of a microarcsecond; because the structural problems in measuring quasar positions are such that most of the sources are self-absorbed at say 20 centimeters and the positions and structure that one is looking at with these sources – one usually looks at two bands – one near 13 centimeters and one at 3.75 centimeters to subtract out the ionosphere. Well the structure obviously is not the same at those two frequencies. This will enter in as an error in the position of the quasar. The quasars also have structural changes as a function of time as these objects evolve, and this I think will limit things to a tenth of a microarcsecond.

Hughes: Did I understand you correctly – a tenth of a microarcsecond – I don't think that is correct.

Johnston: Sorry, no, a tenth of a milliarcsecond.

Hughes: You see, we throw around factors of a thousand here just like that. It's amazing.

Dickey: I happen to have Backer's paper here (NB See previous Ed. note.) and I thought it might be interesting to quote a couple of numbers – this appeared in the November issue of the *Ap.J.*, and he talks about positions of the millisecond pulsar in the FK4 system determined to fifty milliarcseconds and in the ephemeris frame he is quoting an accuracy here of one milliarcsecond, which seems a bit low to me – that's why I was interested in hearing you speaking about it – this is in the abstract. Further on in the article he says that the precision can be better than a milliarcsecond eventually. Some food for thought.

Johnston: The problem with that, which I considered when I was quoting my numbers – is that there is only one millisecond pulsar – all other pulsars seem to vary and have glitches so I would go with the reduced accuracy figures. We have to find several millisecond pulsars if we want to base a reference frame on them.

Kovalevsky: I think we should certainly make a clear distinction between a dynamical frame which a millisecond pulsar can bring us, and so many other techniques which were described by Dickey, but I think that we should really stick to a single fundamental definition of a reference frame which should be the extra-galactic points and then, you study the other ones with respect to the first one, and see whether there is a reason for differentiating them, and I believe there must be some reasons for that. I am afraid if we have different techniques and try to pretend that we are observing the same thing we may get into trouble. I think if the decision is taken to take the extra-galactic objects, we should no more consider the inertial dynamic frame and indeed the word "inertial" already is not very good, because as stated already by Murray, the word inertial is purely local. We have here a method of studying the dynamics of the whole solar system in a frame which is distinct from something built by the observations of the things which you want to study at the same time. It is a good way of separating problems.

Murray: Here – we're back at the same problem – you are then defining a frame with intangible objects – things that nobody can observe – very few people can observe them – so although your frame is beautifully defined it is just not accessible directly. And you've got to define the process of interpolating or extrapolating from these fundamental absolute frames to something that you can actually use as a practical frame.

Kovalevsky: I fully agree with you, but that is exactly what we have been doing for the last 200 years. We defined a dynamical or FK5 system, using 3 or 4 bodies only, and which we do not observe except with great difficulty all the time, and not with respect to stars as everybody knows. And so that is what we are doing already. The observations of the Sun as everybody knows are not so easy to connect to the stars, anymore than to extra-galactic objects. So I think the problem in simply shifting from one type of object to another remains the same, and I fully agree that when I say that we are to compare the dynamical system to the geometric one, you have to use the intermediate one – and we all agree that we need these intermediates anyway.

Hughes: A simple, practical point is that when you are looking at the Sun you use a very small aperture and the motion of the instrument itself measures the large angles, but when you are trying to look at a 19th magnitude quasar, well now you need a big aperture, implying a small field, and that's the operative word(s) – small field. And so although the flow of information is reversed, there is a little more to it than just being faint to bright versus bright to faint. There are some fundamental, oh, there goes that word again, some basic questions that

come up – operational questions – not philosophical questions.

Murray: Yes, I agree I think we're sweeping under the rug the very practical problem of relating a 12th magnitude star to a 19th magnitude object – and we say, oh well, that can be done with Schmidt telescopes or plates taken on large telescopes, but anybody who has tried to do it will realize that you need at least 2, perhaps 3, steps in the process in order to span the very large magnitude range that you've got, and this is where I would like to see steps being taken to get a global, if you don't like the word fundamental, let me just say global reference frame, in the sense of a meridian circle reference frame, at faint magnitudes such as 12 to 12 1/2 which is now possible with the automatic meridian circles. I think this is an urgent need, there is an urgent need for this thing now, to break down some of these photographic extrapolation/interpolation problems that we experience when we try to relate the stars to the extra-galactic objects.

Guinot: I think that this is not a new problem – it is a problem as old as astronomy itself – I think that we should consider only what I call the primary reference given by the extra-galactic objects, as something that we add at the top – but we do not remove anything.

Siedelmann: You have talked in generalities about using the extra-galactic sources as an absolute reference frame – I'd like to ask exactly how you would proceed to do this and whether you would impose any ideal limitations in other words, would you start out with a coordinate system that is orthogonal or not, would you require the system be parallel to the equator or not, would you say we know 100 quasars right now, will those always be the quasars we use – or are you going to increase or decrease them? I think you have to address the question of an ideal definition of the reference frame and then practical rules for realizing it.

Hughes: Absolutely. Probably hundreds of years ago when people came up with the equinox they thought they had found the ideal solution and I don't think any deliberations we will hold here will find the ideal solution. I don't think it would be the end of the world if we had 100 quasars this year and a slightly different set a little later on – we tend to talk about the reference system, that we are going to find nirvana here and that's going to be it forevermore. I think it's an ongoing, evolving process, albeit, at a much higher precision and accuracy.

Dickey: Suppose we do adopt a radio system – one thing that we have to consider is where do we originate the right ascension – one option is to use the dynamical equinox and I think that would be very useful. The other thing we have to think about, is how are we going to define this catalog? Are we going to have a study group set up? For example: Fricke has done a wonderful job with the optical; are we going to have such a mechanism for the radio sources? Which radio source catalog are we going to adopt? Are we going to have the best of both worlds? That is something to consider. Perhaps some mechanism should be set up to get the ball rolling.

Hughes: Well, perhaps before these deliberations are ended, we might take some steps in that direction – I hope so. We have 45 minutes to go – I might say that on the program we have allowed 45 minutes for round table and 45 minutes for general discussion – with that in mind, perhaps we should now relax our formality a bit. Actually, since non-panelists have been contributing, our round table discussion has, in a sense, ended, but I would like to poll the panel, the least I can do, to thank you for your yeoman service, and to see if there are any last comments, anything you would like to say before we formally throw things wide open, and stop our round table discussion.

Jenkner: I would think you should perhaps for clarification ask the community what is actually needed with regard to the precision and density of the, should we call it the intermediate frame, or the realization of the intermediate frame, which is then tied to the, say, quasar frame, – what are the real requirements there? Both with regard to density, with regard to faintness, as Dr. Murray mentioned. When that is well-assessed, then we could perhaps proceed to find out how this could be realized in the not too distant future?

Kovalevsky: Just one comment – I heard remarks regarding the extra-galactic system, where will be the origin – I think this is not important – it can be completely arbitrary, I think we just have to decide where it is just as we have decided that the origin of longitude is determined by the coordinates of the BIH stations. I think we should have at some time, as part of future plans also to have a service to maintain this extra-galactic frame giving more or less weight to such quasars and to such observations, and if one quasar starts to be faint, or one has structure which can't be removed, and so on, then any frame like that must be maintained and we have the work of maintaining it.

Guinot: Same thing – maybe with the addition that the system itself, the primary system, should not be rooted in the primary constants and if some improvement in the system is needed, it should be made in such a way that there is no net rotation of the system.

Murray: I don't suppose there is any difference now from what we have been doing for the last 100 years – producing a catalog which has an arbitrary zero point – it's just set by the numbers in the catalog – exactly the same thing will happen with the VLBI, it will look like a star catalog and be based on an equator because it's based on Earth rotation – in exactly the same way as meridian observations.

Johnston: I think we're a long way off from this reference frame which everyone says is here already – and my viewpoint, since I would be one of the people who would have to go out and make the observations, is that it would not be very easy. In the northern hemisphere there are sufficient radio interferometers so that a reference frame is essentially already established, but in the southern hemisphere there isn't an instrument right now that can actually make measurements to a milliarcsecond. So we have a whole desert down there below minus 30 degrees, full of quasars

that have unknown positions at these high accuracies we are all quoting, so this reference frame we are going to set up today is going to be lacking a lot of different things. I would say that a working group has to be formed – it may even be premature to do that – but one could set up a reference frame for the northern hemisphere, but it would probably take 5 to 10 years to set up a good quasar reference frame in the southern hemisphere – and that depends upon how well the Australian synthesis telescope works and how well VLBI progresses in the southern hemisphere.

(NB The round table discussion formally ends here.)

Morrison: On this question of extending the optical reference frame to an intermediate optical reference frame, we now have the capability, as several speakers have said, of automatic meridian circles which can work fast and go to about the 12th or 13th magnitude. So regarding extending this frame I think this meeting ought to consider setting up a working group which will look at the selection of these stars and what density we should have, so that the transit circles which we now have in operation, and coming on line, can get on with the job of extending the optical frame to say 12 to 13 or thereabouts. I propose we set up such a working group.

Requieme: On the same subject I will say that in the HIPPARCOS program it would not be possible to fulfill that need, because the fainter stars, the stars which will be considered, the distribution will be heterogeneous. The number of faint stars is firm and it includes especially stars of astrophysical interest, and maybe it will be possible during this meeting to emphasize the need for this network of faint stars which was neglected by the proposers of the HIPPARCOS program.

Hughes: I would say this, several people have just mentioned questions of proposals – and we have a little over a half-hour left here. Some people have approached me with possibilities for resolutions, and I feel it is quite proper for this gathering to entertain such a thing. The only guideline, I would say, is; The fewer resolutions the better. I would say that if we could come up with a single resolution that would be the ideal, but from what has already been said, such a resolution of necessity must be rather general in its character to cover all those very legitimate points which have been brought up. I know of one such possibility – and I will call on Dennis McCarthy.

McCarthy: Following the time-honored tradition I just happen to have this resolution which I would like to present. It is a combination of the efforts of a number of people, and it is meant to be broad in its nature and scope. I think it covers many of the things which have already been discussed in this meeting. It is meant to be a draft resolution of the Joint Discussion.

(NB The original text, as presented, follows in quotes.)

"Draft Resolution of Joint Discussion I. (Reference Frames)

Recognizing

1. The existence of inconsistent reference systems that are based on different theories and modes of observation,
2. The significant improvement in the accuracy of observations by new techniques, and
3. The importance of a space-fixed reference system independent of the mode of observation for use in astronomy and geodesy, satisfying the requirements of relativistic theories,

Invites

The presidents of interested IAU Commissions (for example 4, 7, 8, 19, 20, 24, 31, 33 and 40) to form an IAU working group with appropriate sub-groups devoted to specialized topics under the overall chairmanship of the Chairman of the Joint Discussion which will report to the XXth General Assembly in 1988 with recommendations for:

1. The definition of ideal terrestrial and space-fixed reference systems,
2. Ways of specifying practical realizations of these systems,
3. Methods of determining the relationship between these realizations,
4. Possible restructuring of the duties of the IAU Commissions in order to meet more adequately the existing and future requirements for the definition and maintenance of reference frames and to review the definitions of dynamical time and TAI to insure relativistic accuracy of the definitions in the time system, and

Invites

The President of the International Association of Geodesy to appoint a representative to the working group for appropriate coordination on matters of geodetic relevance."

McCarthy: If I could just mention that I feel that this resolution is broad in its nature, and has encompassed what I feel are many of the points that have been brought up today, and as I mentioned in my presentation earlier on Earth orientation and the requirements for Earth orientation, I feel that these kinds of things are required not as something far in the future as we've been talking, but are required right now, very soon, and so hence the requirement for something concrete to be done now, at least by the next GA, so that these issues can be addressed in a way that

something can actually happen. As Ivan Mueller mentioned, we have discussed the proposal of Dr. Guinot about the non-rotating origin for – it seems like 10 or 15 years, and it's never been addressed in a very forthright and sensible way. So, I would hope that this kind of resolution being broad in nature would be sufficient to address these kinds of issues. Hence, this proposal. I have also another proposal – which addresses an even more immediate need.

Hughes: Perhaps we should now discuss the first one.

McCarthy: The second one addresses the necessity for current best estimates of physical and astronomical constants.

Hughes: Could you place the first proposal back on the screen? With that now before us all; may I ask if there are any comments from the floor?

Teleki: May I add perhaps the importance of cooperation between different techniques and people in this field. If we want to have a new reference frame – for this we need observations – and better organizations than those which now exist. For this reason I think that it is very important to have good cooperation with the different observatories, instruments and persons, therefore, it would perhaps be interesting to notice this in the beginning of this resolution.

Hughes: I would say that the resolution, as written, requires probably a degree of cooperation perhaps unheard of previously. I quite agree with what you say, cooperation is needed and is a very appropriate thing. I think the implication of the necessity of cooperation is so strong in the resolution that I personally don't think it's necessary to put something like that in explicitly. I think it's implicitly in.

Wilkins: I think we can say that the MERIT project has already led the way in this in that we have had cooperation between optical astrometry and the Doppler methods, laser ranging techniques and the VLBI and in fact, of course, the MERIT workshop produced a basic resolution along these lines, indicating the need to take on these techniques and developments. Perhaps I should comment on Ken Johnston's point – in fact, the MERIT program has extended into Earth rotation services that which, in a sense, automatically involved the maintenance of the reference frame to some extent, at least among the key sources that are observed regularly for Earth rotation purposes. This may provide the key to your radio source reference. I am certain that this kind of cooperation can work. I've seen it work, certainly on the operational level; perhaps it would be more difficult to get the theoreticians to agree.

Hughes: I didn't mean to imply in any way that this cooperation was impossible – no not all. I am sorry if I gave that impression.

Wilkins: No, no. I merely wished to say that it had in fact already taken place.

Johnston: This is a very ambitious recommendation – but it should be undertaken anyway. We might not have all the answers by 1988, but if you have gotten further along than we are now, than it's a big improvement over where we are at the present time.

Mueller: I would support a working group, but under item 1., it says the definition of, "ideal terrestrial and space-fixed reference systems," – you meant "ideal" – did you? – not just a conventional system? Because if it's the latter, than this would, I feel, delay the recommendation which is forthcoming from the MERIT and COTES groups in connection with this new service. The MERIT and COTES recommendations do contain some specific definitions for a conventional terrestrial and space system for Earth rotation. And that, of course, will be coming during this assembly. Now if this is going to be delayed for the duration of the deliberations of this working group as, you suggest, that would create some difficulty and unnecessary delay.

McCarthy: I would agree, but it's not meant to produce a delay. As I remember, the MERIT/COTES recommendations say something to the effect that this is for Earth rotation, that it is meant to be the coordinate system to be used as a VLBI coordinate system.

Mueller: But we include the terrestrial system there also.

McCarthy: Well, the terrestrial system has not really been defined for the MERIT/COTES.

Mueller: The question is do you mean ideal, really, or do you mean conventional? That is basically my question.

McCarthy: I mean ideal.

Yatskiv: It seems to me there is no need for an ideal system, either terrestrial or space. What is an ideal system? There is a need for self-consistent systems and a need for the transformation parameters between different systems. I am not in favor of that word "ideal." It could lead to misunderstanding once again as has happened previously.

McCarthy: I would be happy to strike the word "ideal" altogether.

Hughes: For my own edification, is the word "ideal" used in this context in some sense of "optimum."

McCarthy: Yes, that's really it, and as Dr. Yatskiv pointed out, we can just drop it.

Hughes: Does anyone else feel very strongly about the word "ideal?" Pro or con? No? Then let us consider it deleted. Let me ask in general – does anyone have any concerns, I'm talking about scientific concerns, which they feel this resolution would not address – if not explicitly, certainly implicitly. I agree with Ken Johnston that this is quite an

undertaking and there is no guarantee that by the next GA everything would be done. But again, to paraphrase Ken, something would be better than nothing. We have been going on for years and years with nothing. Is there any further discussion about this resolution?

Wayman: I think I would like to advise that this should originate from the JD in the name of the commissions. An invitation should go to the GA to form the joint WG within these commissions. I think that's the way the resolutions committee will want to see it.

Hughes: Must this originate in a single commission?

Wayman: No, I think it can originate in a JD all right, but I think it really has to be in the name of the joint commissions represented in the JD.

Hughes: I see.

Wayman: Rather than going from the JD to the IAU Commissions it really comes jointly from the IAU Commissions and goes to the GA and suggests the formation of a WG which may be within these joint commissions. It's just a question of how much it has to be recast by the resolutions committee. I think that's the way it will have to go. It may not seem an important point, but it would look better. Is that understood?

Hughes: Yes, I understand what you are saying.

Wayman: I think you can redraft it later on so that it's in that form.

Hughes: Yes, that could be changed, but that's a procedural question.

Westerhout: Mr. Chairman, may I move that with the exception of some procedural questions the resolution be adopted so that we can continue with the rest of the discussion.

Hughes: Would someone care to second that motion? It seems to be a very popular resolution - let me ask - who is against it? A show of hands, please? No one? Then we can say that the resolution, with the procedural ipso factos and without the word "ideal," is certainly accepted without dissent by this JD.

Westerhout: What about Dr. Guinot's resolution?

Guinot: I think it is reasonably included in this resolution.

Hughes: Excellent - Dr. McCarthy, you have a second resolution, as I recall.

McCarthy: This is a similar resolution meant to address a more immediate need. The issue has come up already today about the concept of current

best estimates for physical and astronomical constants and this is meant to address that issue and I'll read it.

(NB The original text, as presented, follows in quotes.)

"Joint Discussion I (Reference Frames)

Recognizing the importance of ensuring that the IAU system of astronomical constants is rigorously defined and is well suited to current applications,

Invites the Presidents of IAU Commissions 4, 7, 8, 19, and 31 to form a WG to serve in collaboration with the appropriate IAG Special Study Group which will:

1. Review current determinations of astronomical, physical and geophysical constants,
2. Propose appropriate changes in the relevant definitions and values of the constants of the IAU system, and
3. Publish the current best estimates of the values and accuracies of these constants."

McCarthy: As I said, this is meant to address the requirement for current best estimates. I should point out that the International Association of Geodesy calls into being at each of its meetings, the IUGG in this case, a special study group, which is charged with the task of providing the current best estimate at the next meeting of the IUGG. In this way it keeps everyone up to date on what the current best estimates are for astronomical and physical constants and thus we're not stuck with past constants which are no longer valid and which we have no real easy way of changing.

Kovalevsky: Regarding No. 2 – do you mean a new system of IAU constants? When you say "appropriate changes" in the standard values, does it really mean a new system of IAU constants?

McCarthy: This would be the idea of current best estimates of the constants so that if a constant were found to be no longer the current best estimate then that would be so recorded in this publication.

Kovalevsky: But that does not mean a new system of constants – which would have a completely different significance.

McCarthy: That's right – it does not mean a new system of new constants each time – right.

Kovalevsky: But maybe proposing a change in standard values would mean a change in the system of constants.

McCarthy: Maybe just deleting the word "standard" would handle that.

Murray: I'm glad to see No. 2. A small point here regarding "relevant definitions" of constants, I think there are problems with the definitions of the constants. For instance, what is the astronomical unit when you are talking in terms of relativity? I think this must be addressed.

Wilkins: I think it would be inappropriate for the IAU and the IAG to review the determination of physical and geophysical constants. I think this would be seen as encroaching on other people's territory - there are other groups within physics and geophysics doing this job. It seems to me it ought to concern astronomical and geodetic constants. We shouldn't be seen as duplicating the work of others.

Hughes: I might comment that this section could be interpreted such that the thrust is to review what others have done, as you quite correctly say, in order to keep abreast of what others have done in an appropriate way. That's the meaning of the word review to me - in other words, what is going on with these other groups you mentioned? Are we indeed using the values which we should be using? I don't know if that is the thrust of what Dennis is saying.

McCarthy: That's precisely the point - it's just to find out what others are using for these same constants.

Morando: First - I endorse George Wilkins remarks about point one. I think to ask IAU Commissions 4, 7, 8, et cetera, to give their ideas on the physical and geophysical constants - that may be very difficult work to do. I agree that in the past there were discrepancies in some geophysical constants and they appear also among the astronomical constants, that is to say, mainly the equatorial radius of the Earth and it was a pity that there was no agreement at the time. But when you say physical and geophysical constants, that may mean all the values - I don't know, I am afraid we go a bit far.

My second remark is about point 2. Does that mean that from now on there won't be appropriate changes in the system of astronomical constants every - I don't know - the last one goes back to 1936 - but do you mean that now every three years there will be a kind of an updating of the value of constants? Well, that could be so, but you have to think about the people who make the ephemerides and that might be a bit of a problem for them, as well as for the people that make the theories that are not published in the ephemerides but which are used.

Johnston: My interpretation of the recommendation is not to change the values every three years but just have the best adopted values available for people to use.

Morando: Yes, but this is ambiguous because the people who make the ephemerides are the people who use the values.

McCarthy: I don't think it implies that they have to be used in the ephemerides.

Morando: Yes, but it has to be stated. Something should show it.

Hughes: I think the point being made is that otherwise you may have a dealer's choice situation where ephemerides are on any odd mixture of values of various constants – and if that were to be the case it could be chaotic.

Seidelmann: I think I should point out that the constants have some inconsistencies in them and are not being completely used. I would point out that the MERIT project did not adopt the IAU system of constants; secondly, I don't think we are passing a resolution here setting up a working group that will exist permanently. We are establishing one that is to report back in three years – it can be abolished or restructured at that point.

Hughes: Yes, that's a good point.

McCarthy: I think that's the nature of an IAU WG.

Hughes: Excellent point. The thrust of this is not that we are going to change all the constants.

Lederle: I agree with Dr. Morando, only I am not so anxious with respect to the ephemerides because this working group cannot do other than to report to the involved commissions after three or maybe six years and then the commissions would agree to adopt anything proposed or not. But the WG can do only propositions. On the other hand, unfortunately, I must say, the situation is so that not all our people feel bound to the recommendations adopted by the IAU, for instance for the astronomical constants, and nobody can hinder someone from using constants which he regards as better. What the IAU, and in particular Commission 4, can do is only to give advice to ephemeris institutes for their almanacs.

McCarthy: I'd like to point out that this is not meant to cause chaos, but to prevent chaos in the use of constants. If we don't have something like this to serve as a guideline, if nothing else, for users of astronomical and geodetic constants, then the tendency is for many constants to be used and it makes comparisons between systems very difficult and chaotic. So, the intention of this is to prevent chaos by making available to users of constants some guidelines as to what is the current best available, even though it may not be what is contained in the ephemerides or what the ephemerides are based on.

Fliegel: It seems to me that you have a partial precedent in this in the MERIT constants document which was generated by a WG under Melbourne. Would Dr. McCarthy comment – do you believe that this WG that you propose now would operate more or less as the group did that generated the MERIT standards document?

McCarthy: That's what I would envision. Perhaps the product of this WG would be something not necessarily as involved as the MERIT standards

document. Something along those lines.

Fliegel: If so, then you diffuse many of the objections I would have because we already have a precedent which worked very well.

McCarthy: Yes, and it's still working.

Hughes: Dennis, would you characterize this WG as some species of clearing house, in a sense. A filter as it were.

McCarthy: Yes, I think its analogous to what I alluded to as being special study group 100 of the IAG which serves as that. It's a group of people who try to review what is going on in the field and present a list of constants to the users, and so it is sort of a clearing house. They try to make an effort to present to people what is available in the field today - where changes are being made - where improvements are available - and to note them.

Hughes: I would ask if someone is willing to make a motion that we take a vote.

McCarthy: I have moved by presenting this.

Hughes: Alright, who will second it?

Fliegel: I second the motion.

Hughes: Very good - let me again ask for a show of hands from those who are opposed to the resolution as it stands. I see one hand. Dr. Wilkins votes against the resolution.

Wilkins: It always seems to me wrong that one should have motions of this kind presented to a meeting without preceding discussion. It seems to me to be flawed in quite a number of respects. People clearly have reservations about it. The matter should be turned back to the various commissions.

Hughes: Well, indeed, if I understand Prof. Wayman correctly, that's exactly what we do in any event - would you clarify that?

Wayman: I mentioned that in the other case because I thought it to be a commission resolution and it ought to be in the name of the commissions and the JD is the servant of the commissions - it should be put in their name so it becomes a commission resolution. That's quite separate from the question which George Wilkins has made, which was very much in my mind, but I didn't want to make another contrary point, which was simply that this really hasn't been a part of our JD today - it hasn't been the subject of a paper.

Hughes: From a parliamentary point of view this resolution has already been accepted, and this present discussion is, I think, a very nice

gesture towards Dr. Wilkins. We do understand his reservations, and we are aware of them and they are duly noted, but the fact of the matter is that his was the only hand raised in opposition. How many people care to abstain? (NB The chairman was requested to determine the number of abstentions.) Would someone volunteer to take a count – all those in favor of the resolution raise your hand – those abstaining – and those opposed – so it passes once again. (NB Votes in favor were in the majority, abstentions were in the minority, and again a single vote was cast in opposition.)

Hughes: I think Andrew Murray is a little happier to see the mood of the assembly. There are indeed several abstentions.

Kovalevsky: I think there are so many abstentions that I feel something is not there – I think in this particular case, we should refer things to the commissions.

Hughes: I have absolutely no objection to that.

Mueller: From the parliamentary point of view as you said before, the issue is over unless someone makes another motion – but I would like to go back to the previous resolution because again, the comments of George should be valid in that regard also. This was a more important resolution than it seems, and the way it was composed could be misunderstood and it could affect a set of resolutions which could be discussed in other commissions tomorrow or the day after tomorrow. And those resolutions are of a nature which have been worked with by a fairly extensive group of people over a number of years, and they would be most disappointed if the resolution which we passed earlier would in any way damage the outcome of that effort. The MERIT and COTES groups started deliberations in 1978 and 1981 respectively, and they did come up with a definition for the conventional terrestrial reference frame and the conventional celestial system which is recommended, at least for Earth rotation purposes, and it has been the intent of that group together with the relevant commissions, to present for adoption to the IAU for forwarding to the IUGG. As you heard from George Wilkins this morning, the MERIT/COTES groups should continue until at least 1988 or until the new service has taken effect, and it is in the charter of those groups to worry about the definition and materialization of the terrestrial reference frame as well as the others. So I wonder what will happen now with the resolution which was just passed. The IAU will set up another WG under these joint commissions, and both groups would be going their separate ways and creating a confusing situation which would be no advantage for any purpose. So it is very disappointing that the resolution which was presented earlier was not circulated earlier so that people could comment on it. I objected, I asked the question, for example, whether the term "ideal" was intentional or not? If it was intentional, I wouldn't object to it because I knew that an ideal reference frame, terrestrial or celestial, could not be determined by any kind of joint group, but after it was taken out, the effect was just the opposite. Now it is possible that you will come up with something different than the MERIT/COTES group. So there is a

problem here, I know that in the time that is left, this issue cannot be resolved, so I suggest that Mr. Chairman you find some sort of resolution to this problem.

Hughes: It seems to me that we have a solution in hand and I would again call upon Prof. Wayman. Is my understanding correct that, as you put it, this JD is indeed a servant of the commissions involved? Now it seems to me that the commissions do not rubber stamp any resolutions we may pass here – it seems to me this meets the objections of Prof. Mueller in the sense that the individual commissions will have to consider this in their forthcoming sessions during the GA. Is that correct or can it be made to be correct?

Wayman: It certainly can be made to be correct but by being made an agenda item, a commission resolution, to be presented to the GA – if that is indeed your intention to present to the GA. To have it adopted there. Maybe that is not your intention.

Hughes: I assume that that's the intention but I'll ask the proposer.

McCarthy: Yes.

Seidelmann: I think there is a different point of view that can be taken of this resolution. MERIT/COTES addressed the question of a reference frame for Earth rotation. Based on their success in their coming forward with something – this resolution is to try to address a much more general question to answer all requirements for reference frames. I think it's a much broader requirement – a much broader task. I would hope that the WG should show enough intelligence to be cognizant of what has gone on with MERIT/COTES and would not act in violation of it. Certainly if they violated the complete aspect and ideas of MERIT/COTES their proposal would not have any chance of being adopted in 1988. So I think what we're trying to do here is an expansion of what has been done in the past rather than to violate what has been done in the past.

Hughes: Would you say that this resolution builds on the success of the MERIT/COTES?

Seidelman: Yes, that's right, it has to be consistent with what MERIT/COTES did or I don't see how it would be accepted three years from now.

McCarthy: I agree with Ken completely, I think the intention of this resolution is to expand on the MERIT/COTES idea. I wouldn't expect this to have the problem that Ivan's alluded to here. Certainly in Commissions 19 and 31 I would not expect that this would hinder the adoption of the MERIT resolution.

Morando: Another thing which I think justifies that this resolution should be put to the commissions is that it thus proceeds in a way that a JD on reference frame should do; It mentions constants – now what constants; for example, among the IAU system of constants they have

recommended values for the radii of planets. This is a working group, the foundation of which has been passed by this joint meeting, a fact, and I don't agree that all the constants have to do with the reference frames.

Hughes: That's certainly true. Dennis, do you want to address that?

Morando: I'm saying that all the astronomical constants are not linked with reference frames, or you may argue that fact.

McCarthy: Well, I think they are a part of the reference system and, as such, I think they enter into reference frames.

Morando: There I agree, but if you come to that then, everything has to do with reference frames. But then you anticipate what the first WG we have founded will do, which is, and I think its a very good thing, to decide for the future to rearrange what the commissions will have to do in the future – and I agree that perhaps the names the commissions now have are not suitable anymore – that then, will have to be decided by the first working group. But now if you say that all the constants have to do with reference frames therefore a JD on reference frames decides that all the constants would be decided by a WG founded by this JD, I don't agree with that.

Hughes: I don't think that's what it says – this WG is just that – it has no power – it merely can report and perhaps recommend. I would say that in view of the time, and bus schedule, I'll come back to the main point. That is, we are the servant of the commissions involved here – and this proposal will go to the individual commissions, and they will do as they see fit, and if the result of that is that the proposal is not presented to the GA, well, so be it. I think that is the appropriate way to go. I agree that it is not for us to pass the proposal – our vote here was a vote to present the proposal to the appropriate commissions and that we must understand. Having said that, I will entertain a motion from Dr. Hemenway.

Hemenway: Dr. McCarthy said that it was his intent that it go to the GA, I wish to essentially move what you just said – the meeting having adopted the resolution that we send it to the commissions for their action.

Hughes: I believe that is what we must do in any event.

Westerhout: I second that motion.

Hughes: Fine. We are doing, in other words, what we should do legally in any event, which is a good way to end any kind of discussion, on a note of legal agreement. I want to thank all of you for being here today. I hope it was of some interest to you. Let's hope we get some positive results which we will have ready for the next GA.