

OPEN DISCUSSION

Session 3, 14^hGuinot:

I just wanted to make a few remarks and comments on the presentation of Myles Standish this morning. Of course we all have sympathy with the point of view which has been expressed by him. We understand perfectly the problems and difficulties. But I think we must say, that in the recommendations of Virginia Beach, there was a Recommendation V, which in fact covers the point that we still can use TDB when this is necessary for continuity reasons. I would like to show again this recommendation of Virginia Beach, which may or may not be adopted here, which never-the-less has been written in Virginia Beach. Well, it is very safe, that where this continuity with previous work is deemed to be desirable, TDB may still be used, and the explanation says that we should be careful in that case, that there could be some differences, significant differences, in some astronomical constants. So, for the people who still want to use TDB and also TDT, which has now received the name of TT, it is still possible with the full benediction of the IAU. The next point I wanted to make clear is that we may have a difficult task, which is to try to reconcile scientific correctness with practical use. And there may be some conflict in this domain. Never-the-less, I think we shall try to obtain the maximum scientific correctness. What is "scientific correctness?" That is certainly a matter of definition. That is true. Never-the-less, when I hear that TDB is very useful because we can confuse TDB and TDT without harm, I can say that I don't believe that it is scientific correctness. On the other hand, it is rather difficult, of course, to find which is the right way, but it has been very often observed in astronomy that deviating from the principles of a theory for some reasons which are for continuity or convenience in the computations of the users, always ends with some difficulties. As examples of such events, I can say we have this offset of 32 seconds, that is now most embarrassing, which has been introduced for historical reasons. There was some hesitation to shift the origin of TAI for continuity reasons in order to align it with previous Ephemeris Time, and the result is that now we have this embarrassing time-offset of thirty-two seconds. This is an example where we tried to delay a decision, and we are left with some embarrassing problem. Other examples may be more remote in the past, there is the problem of the e-term of the aberration. Well, one day or the other, if we adopt such artificial conventions, we have to regret it, and it becomes more and more difficult to restore the initial simplicity. What we intend to do now is not to force anyone to use TCG and TCB for all purposes. We perfectly understand that some people will have to introduce some conversion factors. An example is certainly geodesy. If we use TCG, and of course the associated GM, in geodesy, we could have a difference in scale factor with measurements made on the ground. And that is an example where people will probably use some scaling factor. But what we wish to do is to define time scales which are as close as possible to the theory so that when people really want to do something they know exactly what they are doing. We don't want to try to dissimulate, just for convenience, or for the sake of users who do not mind about the minor differences between time scales, the fact that these time scales are relativistic time scales, that

there are secular differences between them and that this must be taken into account. This is a completely different point of view than the one which Dr. Standish expressed. We want to avoid confusion, and we want it to be completely clear that there are some differences. Now what people will do with TCG and TCB, well, that is their own responsibility. As I told you at the beginning, TDB and TT or TDT still exist, and people can use them. Never-the-less, I think that it is really the duty of the IAU to have strict definitions which really stick to the theory.

Kaplan:

I support all of the resolutions that have been proposed here. I think it is important that we establish a common terminology and a common paradigm, if you will, for relativistically correct reference frames. However, part of my job is also communicating with the rest of the astronomical community by way of the Astronomical Almanac. I think Recommendation V is on the right track, however I think the language that's used in Recommendation V is slightly grudging and I would like to propose, Mr. Chairman, an alternate version of Recommendation V which, with your permission, I will read.

Hughes:

Please do.

Kaplan:

Unfortunately I do not have a viewgraph for this, but I do have a copy for the chair. My version, this alternative version of Recommendation V, reads, "the working group on reference systems, considering the large body of fundamental work based on Barycentric Dynamical Time (TDB), and it's predecessor, Ephemeris Time (ET), and considering the likely confusion to the astronomical community in introducing a change in the rate of the time scale used as the basis for planetary ephemerides, star positions and motions, and the precession and nutation theories, recommends the use of TT and TDB in developments and publications which affect broad segments of the astronomical community." The note that is currently attached to Recommendation V is fine as is, I would not propose a change in that.

Hughes:

I suppose it's fair to say that the essential difference between Recommendation V as it currently stands and the newly proposed Recommendation V, is that the new one becomes a more positive statement, not, to use Dr. Kaplan's terminology, grudging, but rather recommending the use of TT and TDB in developments and so on. Is that fair George (Kaplan); to say that is the most significant change?

Kaplan:

Yes

Hughes:

I solicit comments, I am sorry we don't have a viewgraph for this. I suppose it would be possible to have one made in a short period of time, but I don't have one at hand. In any event, may I ask, does anyone wish to comment?

Kovalesky:

I do not agree with that new version, because after having shown what is right to do, what is consistent, we cannot say we recommend doing something else. In other terms, we can say that it is still legitimate to use TDB, but after saying that we wish to have common units all over whatever are the reference frames; which we say essentially in Recommendation I, that we are installing something which is consistent; I think we cannot recommend doing something else. We can only say that one can do it, but we cannot recommend it.

Van Flandern:

In Dr. Guinot's remarks I did not hear any comment about the criticism that the constant itself was somewhat in doubt in the last few decimal places as Dr. Standish brought up this morning. And also the discussion here now seems to be centered on what will be in the official almanacs, such as the Astronomical Almanac, which time scale will be used, and certainly the alternate recommendation is that the TDB would still be used for the publication of almanacs. That seems to be the essence of the difference.

Hughes:

I think that's a fair statement. It seems to me that if one can characterize this disagreement with its various levels of subtlety and complication, one may say that on the one hand we have people with very real practical concerns, people who have to turn out ephemerides and have to provide those to the public and they are quite understandably concerned about the continuity of their techniques, methods and so on. On the other hand, there are those who are concerned with what may be called the more purely theoretical aspects involved. Both of these points of view have perfectly good validity. I think that if we could try to accommodate both of these very legitimate points of view, it is likely to pay dividends. Otherwise we go on in the vein that, "the glass is half empty,"; "no, the glass is half full," and that is not a very productive way to do things. Recommendation V is an honest attempt to bridge the difference. I think that both sides in this dichotomy really do appreciate the point of view of the other side, if we could only find a medium in which to express that.

Winkler:

Mr. Chairman, I think that there is an additional point which you have not stressed enough. The additional point is that as long as we maintain scaling, it is impossible to obtain a consistent system of astrophysics because all of our constants would constantly have to be changed from system to system. At this time, we are mainly concerned with the solar system, but there are pulsars, there are other phenomena which are going to be taken up, and I think we have to make the choice clear, that in the interest of consistency we cannot forever sanction what has been done in the past which will fade away as time goes on. What we can do is we can tolerate it, yes, but not more.

Hughes:

I personally fully agree with that, but I wish you had used a word other than "tolerate."

Guinot:

I just wanted to respond to the question of van Flandern in the same way as Dr. Winkler did. Well, concerning the constant, my opinion is in fact given in the draft Recommendations. The recommendation is that the constants be in accordance with what has been proposed, that is, the use of the direct relationship between the various time scales without scaling factors. In other terms, the constants will be expressed in a natural way according to the equation which has been given for the metric form. That is really, I believe, one of the main points of these recommendations, that they propose a uniform treatment of all the constants within the system of coordinates to which they belong. For people who wish to use TDB of course we have to adjust the constants accordingly, but the constants should be expressed in the system which is homogeneous with the coordinate time scales, TCB and TCG that we have defined.

Hughes:

Yes, it is true that early-on in our deliberations in the working group the statement was made that there is practically a symbiotic relationship between the subgroups on time and constants, and that's the point here.

Seidelmann:

I may be muddying the waters a little bit, but I would point out that as you read through the recommendations, no recommendation takes effect at this time, except for number three, and I wonder, based on the discussion here, if it wouldn't be advisable to permit Recommendation III to be delayed in implementation until any of the others will take effect and cause a change. That way we would maintain continuity and cause changes at one time rather than the way it's going now, of changing the time scales today or whenever, then changing the coordinate system and the constants and so forth, spread over a period of I guess up to nine years.

Hughes:

Some of the concepts addressed in these various recommendations are to some degree separable. You can look at them as a package deal, which I think is what you're talking about, but I am not convinced that indeed that is the case. For example the adoption of an extragalactic coordinate frame is, in principle at least, separable, but your point is well taken.

Guinot:

The discussion tends to focus on Recommendation III, but I would like to make clear that Recommendation III is a simple consequence of Recommendations I and II, and if we postpone Recommendation III, we have to postpone every recommendation that we have prepared in Virginia Beach. Anyway, I would not be in favor of postponing these recommendations. The more we wait, the more it will become difficult to adopt some recommendation which in fact recommends changes. On the other hand, since it is still possible to use TDB and TDT, the other form of TT, I see no advantage in delaying the recommendations.

Standish:

I repeat again, nobody has given an example of something we can learn or do better by using this new time system.

Hughes:

Well of course if we could predict every development we wouldn't have to do it, so I don't know. So far we've had comments from just about half-a-dozen people who go sort of round-and-round. I would be very much interested in having comments from some people who perhaps have not made any comments yet. After all, we are trying to come to some kind of consensus here, and one of the great dangers in this kind of undertaking, as we all know, is that it involves rather complicated and subtle considerations, and not all of us are experts in all aspects of it. For that reason I think the more we can get people involved, probably the better off we are. Or, we can end up with a discussion between four or five experts and leave it go at that. Maybe that's preferable, I don't know.

Trimble:

Speaking as a rank outside occasional user of coordinate systems, reference frames and almanacs, I think the rest of the community can quite happily live with whatever you guys decide, as long as you'll provide adequate documentation for us to use it. And from our point of view, a definite decision such that everything is in the same system is probably more important than that the decision be the best possible one, that the good Lord could make for us if he were here to do it.

Vicente:

I was waiting for some other people, who in private have agreed with some of my points, but they don't raise up you see, in spite of the fact that their English is much better than my English, you see. So they just keep quiet. Recommendation V, is not, as I said this morning, consistent with the other recommendations, the first ones, because we are here allowing people to use those time scale systems, so we are adding to the confusion. We try to simplify things, to keep them as simple as possible, and as consistent as possible, in agreement with Recommendation VIII, and here we allow people to use the present-day time scales, and also the recommendation note says that when giving these values, the time scale used must be specified. That adds to the confusion, and I can give you an example. I just learned this morning, from the Director of the Naval Observatory, that when they introduce a leap second, sixty percent of people apply it in the wrong way. That's bad luck because it is a fifty percent probability you see. So now, when we have two different time scales, you just forget to mention which one it is, and it will be a matter of confusion. The previous commentator, she just mentioned we should have a consistent and clear system, and we have heard the main users, the main users, I emphasize that, are not in agreement with these things. And what is going to happen is that we will ignore completely these recommendations, which are for the benefit of a few theoreticians, and we have to take care of the main community of scientific astronomers. So if you adopt some of these recommendations, they will be ignored by most of the users, the main users.

van Flandern:

Perhaps the distinction could be made along the line of the purpose for which each ephemeris is being produced. For example, I think it has been a convention for a long time to publish the Nautical Almanac with Greenwich Mean Time as an argument. The precision is such that it doesn't justify going to one of

the more precise time scales, and a similar argument applies here, where for many practical purposes, the precision does not justify the needs of these relativistic considerations. Therefore, the effect of this change can only be to produce the possibility of confusion or error. The difference however, with the case of publishing ephemerides on Greenwich Mean Time, or Universal Time versus Ephemeris Time and its successors, is that one did not have the luxury in that case of continuing to publish ephemerides on Greenwich Mean Time because one could not forecast the difference into the future. But in this case we can forecast the difference into the future, therefore there is no compelling need for the ephemeris publishers to make their switch as opposed to providing the means for the users to develop the corrections where needed. So perhaps, I'm really now coming around to speaking in favor of George Kaplan's "recommends," that the bulk of the community, for which this consideration is not important, stay with one standard as is now, and the more precise users also have in Recommendation III their needs to be met.

Hughes:

Yes, we don't have a monolithic community here as much as we might like to think we do. There are different requirements, different needs, different viewpoint. Indeed we talk about continuity here, well, even that can be used in two senses. On the one hand, people think of continuity in the sense of not making changes, on the other hand it can be used in the sense of having continuity with established theory.

Kovalevsky:

Well actually I was going to say partly what van Flandern just said. If we speak about ephemerides and so on, it seems we have very well established relationships between TT and TDB and TCG and so on, I don't see what the real problem is. Ephemerides can even put every thing in TT and that's all. And therefore everybody will understand. All we need is a table, such as we used to have between UT and Ephemeris Time, and to have this kind of table available. I don't think at this point there is any difficulty. So far as ephemerides are concerned, I don't think it should be a problem. Now concerning the fact that people present here, like from JPL, have to keep their very complex programming and system, I fully understand. I think Myles (Standish) even said that they did not respond to the suggestion of the IAU to use J2000, but I don't think that's a reason for coming back to 1950. Whenever other people, other groups, in ten years or later, make new theories, new packages, or address new problems, I think it's at that time that it would be really awkward to use something which still has some inconsistencies. I think one of the inconsistencies, that Myles does not think is an inconsistency, but which I believe is one, is the fact that when you go from TDT to TDB, Terrestrial to Barycentric time, the definition of what we mean by a secular term is something which is not well defined, because of the existence of the long periodic terms. And at this level, I think there is also an uncertainty in the way to use TDB, so nothing is perfect here. What we are trying to do is to do it as theoretically well as possible, but maybe it will take us twenty years before it is completely adopted in practice, but if we don't do it now and if our successor twenty years from now started doing it, it would be again much more difficult than now.

Winkler:

Very well, in fact I completely agree with what he said. I myself would prefer to see the almanacs published only in UT and TAI, because these are the times which are immediately available. But let's go through and try to make some progress, and progress in such a situation can, I think, only be made if we separate the issues. The first issue appears to me to be a question of whether we are, in principle, willing at all, as an astronomical community, to formally recognize the existence of relativity theory, because we have not done that yet. We have not yet decided whether TAI is a local, or proper time, or a coordinate time. We have refused to acknowledge that. I think somehow we have to take that step. I think the first step is to agree that the two Resolutions I and II, are the principle ones which, from the beginning, introduce the framework, the conceptual framework, of relativity is real important business, and I say let's first discuss that. If we cannot agree on that principle, everything else will be futile.

Hughes:

I would like to second that. Really, as I believe Bernard Guinot said earlier, from the first recommendation the others follow. So let me ask, who in this room has some reservations about Recommendation I? I mean, should the IAU formally acknowledge the existence of general relativity or not? I use the word "formally." Relativity is, of course, used constantly in some *ad hoc* way depending upon the application. For example, we just had a workshop at the Naval Observatory over a consensus method of reducing VLBI observations, but I said "formally." That's a very important modifier. So no one is against it, so Recommendation I is acceptable?

Fliegel:

As you say, the saving grace is the word "formally." That's what we all agreed upon in Virginia Beach. We all practically agreed that we must account for relativity, it does influence the accuracy of our results. I think part of the difficulty with the resolutions is that relativity encompasses two things; does it not? It includes what we absolutely have to do to maintain the accuracy of ephemerides. We all agree that where accuracy is concerned, we do more than acknowledge relativity, we implement it. But for the other concern; a theoretician would like to have a rigorous transformation between where the Earth is, to where the barycenter is. He would like to account for the potential difference between the Earth's orbit and the barycenter. That involves a frequency offset. We don't need it to maintain accuracy. It is simply a numerical transformation, like calendar reform or a currency reform, and we are telling you gentlemen, that although it would be desirable to reform the calendar, and also to have a rigorous transformation to the barycenter, it just involves too damn much trouble. We can't do it. We can't convince our parent organizations to do it. Where accuracy is concerned, we will acknowledge general relativity, but we will not introduce what is primarily a numerical change just to acknowledge the potential difference between Earth's orbit and the barycenter. No one is going to make observations at the barycenter, so it does not matter.

Hughes:

Well, I'm glad you acknowledged the formal nature of the case. The other

point: I don't think there is anything in any of the recommendations that forces you to do any of these things. That's a very important consideration, because the points you have just made have been made, in different words, three or four times in the last hour here.

Standish:

Maybe I should ask, when the IAU makes a recommendation like this, and if the wording says somebody "may continue" to use something, if that weren't there, would we be forbidden by law to do it. I mean, let me ask, what are the recommendations for? In a practical sense, person by person, looking into the future, what are these recommendations going to allow you to do or not allow you to do? And I again go back to the example that George (Kaplan) made this morning, that M. Soffel was able to do something more easily because he was using TCB instead of TDB. Fine, I agree. I mean, he could have done it whether these recommendations pass or not. Is this allowing him to do his derivation or preventing him from doing it if we don't pass it? On the more practical side, if we pass this, is this going to dictate to ephemeris users that they have to go to this, or ephemeris makers that they have to make ephemerides in this system?

Hughes:

I don't think so. That's not my reading, no.

Standish:

Is this going to dictate to the *Nautical Almanac* people that they have to print their blue books, or whatever, or the *Connaissance de Temps*, in a new time scale that's going to confuse the public?

Hughes:

No, I don't think that there are any words to that effect in any one of these recommendations.

Standish:

How about all this electronic stuff that we are talking about? How about the ephemerides that have been produced that now go into the future? You are going to have printed tables that are on one system and printed tables that are on another. I can't see that it enhances the science at all. All this recommendation is saying to me is, "Hey look guys, all of a sudden we think we understand relativity, and now we want to adopt it, and wish we had understood it maybe twenty years ago." I don't see the politics, who was supposed to do what, and who's allowed to do what, and like Henry Fliegel just said, it doesn't matter what this says, a lot of people are just going to ignore it. So where are the limits of what we are doing? Are they defined at all?

Hughes:

Well if I may respond to some of that. Regarding your Soffel analogy, I can make a counter analogy. You and Henry (Fliegel) want to be able to talk to one another, you want to be able to talk to your customers, quite so. I think maybe Soffel would like to talk to his peers as well, and do things in a common framework in a theoretical way. There are parallels you can make there. By the same token, you can do what you want to do. If every piece of paper we

have here were to burn up instantaneously, it would have no effect on what you do. You can do, just as Soffel can do, what one wishes, certainly. I don't deny your argument, I just say that it applies across the board.

Kaplan:

I want to make a point about the ephemerides, and that is that, number one: it's not just the blue book. The blue book is just the thing that everybody thinks of when you think of the ephemeris. But these days, of course, we're producing quite a lot of computerized data, we're producing algorithms, we're producing even subroutines which are distributed. So it's much broader than just a table of numbers in a book. But, if you think about the table of numbers in the book, I need to point out that we also not only produce geocentric right ascensions and declinations, but we also publish sections of what amount to be barycentric planetary ephemerides. We do publish the rectangular coordinates and velocity of the Earth, and we publish heliocentric coordinates of the planets, so this does directly affect, in other words a switch from TDB to TCB, will directly affect what goes into the blue book. I am concerned about the interface with the users of the blue book, the rest of the astronomical community that is not in this room. That's my concern. I am fully in favor of all the recommendations, I think in fact they do establish a very clean theoretical frame work that we can all use in the future, and which will help communication among ourselves, that is, among the hundred or so of us that are in this room. My concern is with the rest of the astronomical, and indeed scientific, community. The geodetic community is also a heavy user of what we do, and we should not just talk to ourselves. We have to remember who else we are dealing with here, the other people who are not in this room.

Davies:

I am sort of a representative for that group which might perhaps be called "non-JPL," but which works with the JPL space programs. So I am quite used to communicating with JPL people like Myles Standish, and in fact they are one of my primary points of communication on issues like that which we are discussing today. There are some points which I find disturbing. For example, I am on experimenter teams, and we say we want J2000 for all of our results from, for instance, a Galileo space craft. So the project says, "yes, we'll give them to you, of course our software runs on 1950, and we will not pay to modify it because we can't be assured that the program could be modified in time. So we will compute in 1950 to command a space craft, but we will convert all of the results then, but on the side, so you will never know the difference when you read them." Right now, the Magellan space craft is in orbit around Venus, and JPL's navigation team is doing their thing as they do with these things. It's all being done, I think in J2000, at least as far as I know because I never see anything different. We insisted on J2000 all the way though on the Magellan project. But right now, we have some Soviet guest investigators, and they are dealing with the Venera 15-16 data, and we are doing some joint exercises between these two flight missions. Their data is all in 1950, of course, and it is extremely important for us to try to improve our knowledge of the physical characteristics of Venus by reducing the data to a common system. If we have a little bit of trouble communicating with the Soviets, and we put more things between us and other groups internationally, this brings us to one of the primary functions of the IAU. As long as I'm

talking to JPL, I don't need the IAU, but when I am talking to the Soviet Union, we use a "short hand." We say, "we will convert ours to the IAU system," and they say, "fine, we understand the IAU system, and we will do that." We don't have to go through all of the little letters of characterizing time or coordinate systems. So, I just wanted to express that, I think it's true throughout the community that is operating large expensive space missions. We heard from other people, I'd like to hear from the French and the Hipparcos people as to how they plan to operate their space craft and in what system. Could we communicate with them?

Hughes:

Before you sit down, since you represent a new voice may I ask; what is your feeling on the question I asked earlier about Recommendation I? If you care not to comment that's fine, but would you?

Davies:

I've no objection to it, I think we all recognize the impact of relativity, but I'm not sure what an IAU recommendation does or doesn't do or is supposed to do or not do. In general, for example, I wrote my last report and used TDB in it, and the editor said, "explain what this is, what does it mean?" So, I just overruled it, saying, "everybody knows what that is." Deciding that those who didn't know wouldn't learn anything by reading a half a page of what it meant. So I think that it's really a matter of communicating. I think the scientists that work in one field develop their own habits of how to deal with relativity. It's a question of how large that community is versus some other one, and in doing it in a practical way. As I said, the most useful thing I've found is that by saying "IAU conventions" we can communicate quickly without going through these series of ten resolutions, and trying to be sure that you understand what each one really means. It takes an attorney, you know, to do that, if you are not working with these parameters professionally.

Winkler:

I think there are really two issues. Number one, what is the status and the purpose of an IAU resolution? You have in part answered that, by pointing out the usefulness of having some guidance. But of course it is a guidance behind which no policeman can be found. It is based on entirely voluntarily cooperation. The purpose of our deliberations here is to provide guidance and new concepts, and it would be useful if most people, but possibly not all, would adhere to them, because it simplifies communication. Exactly what you said. And that I think, is the answer to Myles' (Standish) previous question. What are we going to better if we continue to evolve our conceptual system? What we are going to do better in the long run, will be to have better communication. Of course, our present deliberations are hindered by the additional aspect of the cost of conversion, and I suggest that is not necessarily connected with it. If we always keep the cost point in mind, we will be prevented from including or creating new concepts in the future, or standardizing our concepts. I think that would be a grave mistake, and that it would be counter to the very purpose which you have explained. So, to summarize, the status of an IAU resolution, is that it is a voluntarily recommendation which would be useful for scientist to follow in order to simplify communication. Otherwise we have a hundred-thousand standards to

use where we may have five or six. Great advantage for the progress of science. The second point is that the aspect of cost of conversion should not enter when we talk about defining better concepts for the future. We can avoid the conversion problem completely by saying, "alright, continue as you want," but we should recommend that new work be in these and these concepts. So again I recommend trying to separate the issues, because we cannot solve everything at once.

Guinot:

I believe that the proposals of the recommendations, as we prepared them, is precisely to provide a simple and sound basis for all of these activities on the reference frame by defining constants, time scales and coordinates which are as close as possible to the theory with a minimum of convention. But of course, there is encouragement to use these recommendations, but it does not force anyone to do it. Never-the-less it provides the common language which is needed, and it draws the attention to the fact that there may exist, in fact, in the practical use of time scales such as TDB, problems arising with scaling factors. I would like to add that it is a pity to have defined time scales like TDB officially, since it is not really well defined. It is somewhat ambiguous because the way you remove the secular term is not really specified, and is dependant on the averaging time and the method you are using. But this may be a secondary problem. The main problem is that we need, and we are trying to provide, a common basis. There have already been errors made by using scaling factors incorrectly. I am quite certain that if people would have had these definitions of the basic time scales, like TCG and TCB, such errors would have been avoided. However, once again, these definitions do not prevent people from using TDB if they wish. It is in fact authorized by resolution V. On the other hand, Dr. Vicente has said that Recommendation V is not in line with the previous recommendations. That is true, but Recommendation IV is also not in line with the previous recommendations. It defines a time scale, TT, which is an exception to what is proposed by the previous recommendations I, II and III. This time scale, TT, is proposed simply for the benefit of the user so that the ephemerides can be expressed in a time scale which for any practical purpose can be represented by International Atomic Time, TAI, with a constant time offset which is available to any user.

Vicente:

I should like to make three comments. First, someone said, "well, in the future we might need these definitions so we can start now." Well, I think that if in the future they need a better definition, they will do it in ten years time much better than we can do at the present time. Probably there will be better research at that time. So I think we can postpone that, if there is really a need you can do it later on. Second point, was from our chairman, who remarked that of course these recommendations do not bind anybody, and indeed if Soffel wanted to use the relativity corrections or the cosmologists, they could, if JPL wanted not to accept them, they could do it. The difference is that the cosmologists are very few, and JPL is a very successful group that has sent many space missions. So I think the number of people, and I think that's the main point of the astronomical community, is to satisfy the needs of the majority of the astronomers, not of a few concepts, and I think that's extremely important for the astronomical family people, for the time services

people and for the space missions people. The third point is a question of a point of order. When you said about voting on Recommendation I, you said the people who were against it stand up. Well, I would prefer the other way around you see, the people who are in favor of it would stand up because you see what will happen is after such a good lunch, most of us have had a good lunch, most people will be sitting down you see, so I think that's not a fair way of putting a question.

Hughes:

I wasn't aware that I had done such a thing since no "votes" have been taken here. As I recall, I requested written votes by mail from the WGRS which, by some good fortune I have with me here. I don't think, however, that I asked anybody to stand up. I asked them to check something. But be that as it may, I have one reaction. We have to be careful doing science purely by democracy, otherwise we would still have a geocentric universe. So we must be a little careful with that sort of thing. Not to denigrate JPL in any way. Certainly they represent a large community, they must be considered, but you know, if you have one or two theorists working away in some garret, I think maybe they are pretty important too, even if outnumbered.

Mignard:

OK, I wanted to say first that I personally support strongly the various recommendations one to three about the use of new time scales. The point I want to make is that one of the first difficulties we encounter when you learn or teach general relativity is with time and time scales and the relationships between the abstract letters put on the blackboard with the actual time scales constructed by astronomers. And now, for the first time I think, we have a chance of entering definitely, and in a clear way, in the work of general activity by defining time scales and constants within the theoretical framework. And for me it would be unimaginable to miss this chance by postponing, or by keeping some alternative way by changing Recommendation V. If you recommend the use of the former time scale for the publication of almanacs, it is the same as saying that what have done by the working group is not useful, it has no interest, and I oppose strongly such use of Recommendation V. As far as its usefulness, the point has been raised by Myles Standish, the usefulness be defined as, "what can we do better with these new time scales that we could not do as well before?" For me the fact that the two, new time scales are well in keeping with the theoretical framework of general activity is the main usefulness of these new time scales. It is sufficient by itself to derive, and to define, time scales based on a theoretical point of view, which is completely consistent from a to z.

Hughes:

You raise a very interesting point. There is another community which we have not even mentioned, and that is the academic teaching community. There students learn about changes when you carry clocks about the solar system, but then we find that the IAU doesn't quite see it that way. That's a good point. I think that's the point you were making, among others certainly.

Standish:

I strongly object to the wording that you have used, Jim (Hughes), implying

that if we accept this recommendation number one that we are accepting relativity, and if we defeat it, we are ignoring relativity, or claiming it does not exist.

Hughes:

I never said that or implied it. I refer to my word, formally, again, that's crucial.

Standish:

That's nice of you to put that in. And implying that we are giving the impression to the academic community that we are not using relativity.

Hughes:

Well, as a matter of fact I suppose that's, in some sense, a fair statement as far as TCB versus TDB is concerned.

Standish:

There is nothing unrelativistic about that at all. I am sorry, one time rate is just as valid as another one. Somehow we have gotten into the parochial viewpoint that the whole thing goes from an SI second, counting transitions in Paris or in Washington. If you want to really go back and step far away, maybe we should start outside our galaxy and then start making transformations in. I don't think mother nature decided that the basic time independent variable originates in Washington and Paris. So I can counter your argument, and you are now going to counter mine with something saying, "hey, be practical, we have to measure this thing," and I agree with you, but we also have to be practical in other senses also. So please don't start saying relativity or not relativity. The only issue here is what have been invested in the past, and an ideal which certainly if we had adopted two or three decades ago, we could live with much more easily. But there is nothing scientific being violated one way or the other.

Hughes:

That's true, but one can couch the issue in terms of the use of SI proper units, that's one way of looking at it.

Winkler:

I think there's a misunderstanding. The Cesium standard, the SI standard of measurements, is a proper system of measurements. Wherever you have a Cesium clock it ticks off seconds. The relativity effects are effects of the metric, the metric of space-time, and the question really is whether we should assign a different frequency to the standard at the barycentric, or whether we should adopt a principle, which we have recommended, to use the SI system consistently, the same frequency everywhere. I don't know now where the problem is because, if you claim that the SI second is based on a Cesium atom in Paris, it is wrong.

Fukushima:

Well I would like to express my personal observation that I can stand multiple time-like arguments, but I can never stand with multiple values of constants. Can you imagine these multiple expressions for GM of the earth? I cannot

stand them.

Hemmingway:

This is just a question out of ignorance, I suppose. It seems to me that Myles' (Standish) objection is the fact that the two rates, the one used in his ephemerides and the one proposed are different, but it is just a basic difference in rate, and I don't understand how the theory of relativity can depend on the exact value of the choice of the difference of rate. So wouldn't it be possible to pick the rate and adjust the theory to match the old time system. I don't understand where the problem is at a fundamental level.

Hughes:

The question is, we have adopted the SI proper units, and do we want to maintain them as the standard throughout the solar system or not? That's one way to phrase the issue. Beyond that, I refer you to someone else.

van Flandern:

First a question for Myles (Standish), and then I wanted to make a motion to the chair. Myles, you had this morning spoke in terms against Recommendation III, do you have any reservations about George Kaplan's modified wording for Recommendation V, and leaving Recommendation III intact for the people who need it. So that for example, for the principle almanacs, the IAU would still recommend the usage of the old time scale. Any reservations about that?

Standish:

I don't think I even have reservations about Recommendation III until the attempt is made to force it on somebody. That's my reservation. I can live with the new recommendations. Effectively, to me, I can almost see that in the future what they are going to be is a convenient nomenclature for people to operate with, and this is fine and certainly it also maybe clears up an academic concept. When it then becomes something that is forced into a community, which has sadly enough, something established which maybe is not optimum, but certainly works, then we are introducing a danger. And I'm not speaking about JPL. Again, I've sent ephemerides to four hundred groups, and these things go on into the middle of the next century, and some of them go on to the year three-thousand. People have used them, they printed tables, and so forth, and now all of a sudden are we going to force this into the ephemerides and the almanacs and so forth? Now you will create confusion and chaos. But certainly it's striving for an ideal, well-expressed relativistic system, I'm certainly in favor. But it is where the IAU stops and starts, and forces something upon somebody else that concerns me. I'd like to ask Bruno (Morando) what would the French do? Do you have any feeling?

Morando:

We at the Bureau de Longitude are very respectful of the law, but what we do is, we just print at the end of each page of the *Connaissance de Temps* that, for all practical purposes, the time scale is TAI plus 32.104 seconds, and that's all. So what I mean by that is, I think we are conscious that all these points, these things, have to be clear, and surely they weren't clear before, and there were problems. So I think I'm in favor of the recommendations, because at least we have something which seems to be clearer. But as far as

users of ephemerides are concerned, you have to make things as easy as possible for them. They don't bother about understanding what's behind, you read your clock and you add 32 seconds something, and that's the time scale.

van Flandern:

Mr. Chairman, unless this is perhaps not in order, I would ask a point of order. There is a motion on the floor from Dr. Kaplan, to alter the wording of Recommendation V, and the discussion has, to a large measure, centered on the desirability of that. And if it is in order to just substitute the wording in Resolution V now, I would move that question, unless you prefer to wait till the next session to do that.

Hughes:

Let me reiterate something that I said this morning. It has to do with the legalities and niceties of these proceeding. I have checked this with the IAU executive, specifically secretary McNally, and he confirms my understanding that it goes like this: Here, in the Joint Discussion, we are discussing, explaining and perhaps enlarging upon existing recommendations from an IAU working group. Now the only organization that has the power to change those recommendations is the working group itself. So this joint discussion cannot do what you just suggested. However, the working group will be meeting later today, and certainly I am sure this will be one of the things which will be considered. Now that doesn't mean that the working group is the end-all and be-all, because as I said this morning, next Monday afternoon in Sessions three and four, there will be a Joint Commission meeting of the sponsoring commissions, of which, as you know, there are many. It is that Joint Commission meeting which has the parliamentary power to elevate these recommendations to the status of resolutions, commission resolutions, or not to do so. I would say, that although we don't know what the working group will do today, regardless of what they do, the sort of thing you are talking about would be properly entertained at the Joint Commission meeting. I've been very careful to check this formally, as it were, because the last thing that we want is improper procedure.

Seidelmann:

I'd like to make a couple points. I am a little bothered by the statements, or the implication, that TDB is wrong and TCB is right. They are not really right or wrong, they are different and more clear one way or the other. The other thing is that I think while I, and I think most everyone, supports the resolutions in their implication and their meaning and their purpose for the future, the real problem is how to get from here to there. There is no implementation date. For instance, if you ask when are they going to change from one time scale to the other for publication, there is no recommendation, no date, so then we will face the problem that the French will do it one year, the Americans another, the USSR another and so forth, and JPL will continue with theirs as is. So there is no way of changing from here to there. It is going to be a period of confusion I am afraid. The other point I'd like to make is nobody has talked about the epoch J2000, and what time scale is J2000 on. In practice I think that the statement would be that the FK5 has been published on J2000 on TDB. The difference is not significant in that case, it is significant when you talk about that epoch and the ephemerides of the

planets. So you have another change involved as you change the time of the epoch.

Hughes:

It's true that the introduction of a new time scale into the ephemerides represents a definite discontinuity that requires some kind of coordination and collaboration. But in the general case however, I think someone earlier mentioned elliptic aberration, and if one looks back into the history of elliptic aberration there may be an analogy. I know the analogy may be strained a bit, but not too much. In case anyone does not recall, the elliptic aberration is that part dependent upon the perihelion and the shape of the Earth's orbit. It is a small, slowly varying quantity, and long ago, when we had tables of logs and green eye-shades, for convenience that part of the aberration was left in the mean places and so it stayed. That practice went on and we all became used to it. Indeed, the almanac offices, when the IAU changed to actually computing the aberration on the basis of XYZ's and their differences, would get a perfectly good value of the aberration, which they then would ruin because after all, elliptic aberration was supposed to be in the mean places. We went on this way for many years. Well, then the radio astronomers came along, and I can remember reading articles back in the early days of radio astronomy where they referred to this "quaint habit" on the part of optical astronomers of leaving the elliptic aberration in the mean places. Well, that was a chuckle, so to speak, and many of them blithely ignored it. Well that started a trend and finally, when we went to the J2000 system, we took care of the elliptic aberration in an appropriate way. Now I admit my analogy is strained somewhat, but in a similar way I think these time scales will stand or fall on their own merits as time goes by, and I think we should be a little hesitant to mandate some hard implementation date. Although you have a good point Ken (Seidelmann), certainly you do, I don't think that it is the intent that as of a certain date, or after this General Assembly, there is to be an end of something, and we must switch over. There should be sort of a gradual evolutionary process here. I think what these recommendations are trying to do is to lay down the tracks into the future. Let's see who takes the train.

Seidelmann:

I hate to belabor the point, but you've made a different point inadvertently because I think you ought to look back at the change in elliptic aberration and how it was handled. Because by prematurely, and without thought, introducing corrections we went through a period, from something like sixty-eight to seventy-five, of completely botching the situation. So it is my concern that we don't do something like the change from using elliptic aberration to not, by going through a period of complete chaos and making all of the mistakes we could. This is what happened.

Hughes:

That's absolutely right, but we didn't have recommendations then, and that was the problem.

Johnston:

I just have one very short comment, and that is that we better either adopt

something or not adopt something, because if we go with this recommendation where you can actually use what you please, there will be general chaos. I mean, what I'm hearing is that you'll recommend that you should use it, but I think we have to come up with a consistent set of units, and just stick with them. This is for posterity because one of the things that we had in the past, like elliptic aberration, radio astronomers could go back and look at the positions of stars and we knew that that wasn't in there. When you do that correction you don't want to have the correction for elliptic aberration. So what we have to do in adopting this new set of constants and other things, is to come up with a consistent set, and say, "this is what we recommend." We can't sort of step back and say, "you can use it or you can't use it," because people have to know what they have to use when they make a consistent set of measurements. The data will live on through posterity, the theories will change slightly as time goes on, I think what the gentlemen here are trying to attempt is to have it so that what we are doing right now is as consistent as possible with theory. But I would like to say that what we want to do is have things be as correct as possible. We have to adopt a standard set of units.

Abalakin:

I can see that the present status, because of the word "recommendation", is not an obligatory law, and such could be followed or not. But at the present time, it is a result of the fruit of the efforts and work of many specialists who have done their work properly and correctly. Nobody could have some objections about the correctness of the results in terms of the General Relativity theory. I have in view the works of Soffel, Lestrade, Damour, Brumberg and other colleagues, and so we must "prepare the way of the Lord," that is, the way of the higher precision of future investigations. So, the recommendations must be adopted in my view. As to the users, I think it's a task of people who deal with ephemerides to make very clear explanations, in their almanacs, as to what is done, and what must be done if people need some lower degree of precision, and if this is done, and every relationship is explicitly formulated, it will facilitate the work of the users. It was mentioned here that our space people have used the Equinox B1950 until now, and they never felt inconvenienced. I think when we have recommended to them another set of astronomical concepts, another set of parameters, and nutation tables, and so on, they will be used because it will be clearly stated from the beginning what we are dealing with.

Hughes:

We are now at what I might call the breaking point, so I would ask that we take a one half-hour break and return at four o'clock.

OPEN DISCUSSION

Session 4, 16^hHughes:

Dr. Brumberg has requested a few minutes here in order to make a statement. This will start our final session.

Brumberg:

I don't want to repeat myself, but I would like to make two comments. First of all, I cannot agree with the statement that the time for new time scales has not come yet. Even now, if we look, for example, at the equations of motion for Magellan, we see many scaling factors for mass and for coordinates. And of course this makes much trouble for people who are engaged in the analysis of Magellan's observations. And these time scales are very important for geodesic purposes, because if you want to obtain coordinates of earth sites to a millimeter precision, and this is now the aim, of course it's necessary to be very accurate with both our time scales and the relativity aspects. Moreover, in analyzing millisecond pulsar timing, now people use not only barycentric time and barycentric axes, but even galactic time and galactic axes, so the time for our rigorous time scales has already come. And second, the name Soffel was mentioned here several times, and that's why I want to read a remark from a joint paper written with him and presented to Celestial Mechanics. This paper is written in the form of questions and answers, and is intended to explain, for non-relativist users, the problem of relativistic reference frames and time scales. One of the last questions is: "Why do "theoreticians" and "practical men" seem to have different opinions about the introduction of time scales such as TCB and TCG? What speaks in favor of, and against, such an introduction?" The answer given is as follows. "Maybe you know the saying: the best is the enemy of the good. Practical men had made all kinds of efforts to produce high quality ephemerides based upon TB. These ephemerides have been distributed all over the world where they have been implemented for other purposes than astronomy or relativity. Then come theoreticians who claim that TCB and TCG are better time scales than TB and TT. Practical men argue that introducing TCB and TCG would demand many changes in existing software and could lead to serious mistake among the user groups ("a spacecraft might even crash as a consequence of confusion about time scales"). But TCB and TCG have not been introduced for the sake of theoreticians. TCB and TCG are defined as coordinate times of the corresponding reference systems, and may be introduced with arbitrary accuracy. In contrast to this, TB and TT are defined ambiguously by splitting functions, depending upon the evolution of the solar system, into secular and periodic parts. This practically means that one has to deal with many different realizations of TB and TT. Let us consider workers in the field of planetary ephemerides. Let us assume that the barycentric time scale TB is used as argument of the dynamical equations of motion, and that practically TB is obtained by using some approximation formula for the periodic differences of TT and TB. Then the motion of the planetary system will show spurious effects due to the use of some only partly useful time scale. In principle the same is true if these periodic differences are derived by means of numerical integration, because the results will depend upon the period of integration. Moreover, using TB

as barycentric time means that the natural unit of TCB has been rescaled. This implies that not only one unit of time, like the SI second on the geoid, or in the asymptotic region of the barycentric system, is used, but at least two. This has a great disadvantage that all dimensional quantities have different numerical values in the barycentric and in the geocentric system. For ephemeris work this mainly applies to the values of solar and planetary masses, GM_i . If TB and TT are used as fundamental time scales, then the numerical values for GM_i are different in the barycentric and the geocentric systems. Satellite people, working in a geocentric system, will have to use different masses for Earth, Moon, Sun and planets than the planetary ephemeris people. One should always have this in mind before one votes in favor of TB and TT. Very likely, further use of TB and TT will, therefore, also lead to confusion. The argument of practical men that the corrections from the observer's proper time to TB is much smaller than those to TCB, cannot be regarded seriously when numerical calculations are performed with a large number of significant digits." So, you may regard this as the opinion of Dr. Soffel, who was so active at the Virginia Beach meeting. I am not so active, so I try to express his opinions here.

Hughes:

I would now propose that we, at least for the time being, drop the subject of time. We have concentrated exclusively on that question, and I think that the points of view have been adequately, indeed eloquently, expressed. However, I would remind you that we have a Recommendation VI and a Recommendation VII dealing with spatial matters. Of course, in addition, we have one of the most important recommendations, Recommendation VIII, which already has an eloquent spokesman. (NB Recommendation IX was not discussed since it was clear, even at the Colloquium in Virginia Beach, that the overwhelming majority favored it.) If I may, to start this matter, call on Christian DeVegt. During informal contacts with him, he indicated he might like to make some comments about Recommendations VI and VII, dealing with extra galactic reference frames and a working group and so on.

de Vegt:

Yes, I would like to make at this time, since we are talking of the working group, a few comments. I would like to remind you of some special aspects, and that is mainly that there is still a big gap between the understanding of what kind of sources we shall use and what the relationship to the optical reference frame is, because there are a lot of users who are really fully satisfied with the radio reference frame. On the other hand, going into the question of galactic kinematics and so on, we would like to transfer the high quality of that reference frame to the optical side, and of course Hipparcos is one of the future answers to do it in one way, but Hipparcos is not the only answer. I mean even if Hipparcos will give a perfect solution concerning its net of stars, it is one snapshot, it is at one epoch. We have to see to it that we do not fully depend on this approach, and that we are open to consider, in a broader sense if necessary, how we can get the connection and satisfy the needs of optical astronomy in a more general way. My point is, for example, the nature of the sources. I heard this morning the statement that we are already on the level of a hundred microarcseconds and quickly approaching a microarcsecond. Well, that might be true in a formal sense

concerning the mean errors of some calculations, but it absolutely ignores the nature of the objects, of our targets, and this even holds for stars. Therefore, I feel that we should be sensitive that our targets in all reference frames are really capable of giving us this accuracy. The connection to the optical frame and the related optical work have to have more importance, similar to the great success and the importance on the radio side. The latter works fine, but in the optical we only know, for a small number of sources, little about the structure and about the optical properties. For most of the sources we don't know anything. Even the magnitude may change by two or so within a few weeks.

Kovalesky:

Well, I can only concur with what was said by de Vegt. I think our various recommendations insist on all these principles and on the necessity of much more accurate and numerous observations. I would go even further by saying that it is not because we would have had Hipparcos and would define a kind of first epoch optical reference frame, no, that game is over completely. I think the main big job for the astrometry of bright stars will be, during the next twenty years, the maintenance of the system. Maintenance using three or four hundred radio stars, which means also that we have to study structure, what exactly is the emitting point, and also using some other ways and other instruments to link whatever we can with them. And I think it is not the end of bright star astrometry. That is far away.

Hughes:

If I may add to that, you mentioned new techniques, and one such is the development of what we may call "optical VLBI." The day is coming, for example, you mentioned twenty years, in twenty years we may well have an optical system which is, maybe not on a par, but certainly competitive with the radio system. Optical interferometry today stands where radio did about a decade or two ago, and technology will not stand still. That's not exactly aligned with our recommendations, but we do use terms like "all observing techniques" should be used, and that certainly doesn't mean just established ones. And I might say that the possibility of direct linkage between extra galactic objects and galactic stars using optical interferometers is certainly a feasible, practical and attainable thing. Any other comments on these resolutions? Apparently these are, compared to the time resolutions, benign and acceptable with no difficulties?

Johnston:

I would like to reinforce what my two colleagues have said; that it's going to be a long road before we have reference frames at a tenth of a milliarcsecond. Consider the quasar reference frame that we're all rushing to get into effect. When one looks at those objects they all have sizes on the order of a few milliarcseconds, and they are observed in two frequencies, S and X band. I am sure that we will see proper motions in those objects as we see the sources vary in time, there may be proper motions, not the way we are talking about, but just that the energy from those objects is along a jet and moves out along some kind of an angle, and so we may see some "proper motions" on the order of a milliarcsecond or two in some of those positions. And so I would be very careful in going ahead in haste and saying, "we're going to make these fifty

objects our reference frame." I think it will take us many, many years to do that, and there's an even bigger problem if we look at relating the optical and radio reference frames. Most of the objects that we have that have radio emission are stars, binary stars, so we are going to have to determine the orbits of those stars in addition to their proper motions and distances, so its going to take quite a few observations to do this. It will take many, many years to obtain these observations, even if VLBI is successful, and can actually measure say radio stars to a milliarcsecond, then we will have to take out the orbits and that's going to be a big job. So, we have a long way to go, and I think what we will end up with for the reference frame is probably a working group, that will go on past everyone's (in this room) life times, to try and get a reasonable reference frame at these high accuracies that we have been told about, the tenth of a milliarcsecond. Right now, we probably can, in the radio, give you a reliable reference frame at the order of a milliarcsecond.

Hughes:

That's an extremely important point which was mentioned earlier. In fact, one can make a connection between your comments and some of Ken Seidelmann's earlier comments about implementation and related questions. We do have a mix here. I quite agree with you, we are talking about decades of effort here in the long run. It's not something that can be done quickly, we can't create reference frames by recommendations or resolutions that's for sure. Does anyone else wish to make any comments in the general area of reference frames as addressed in these two aforementioned resolutions?

Standish:

I have a little bit of concern about Recommendation VII. The "considering" section talks about the equator and equinox of the FK5, and then the recommendation part of it says that we try to get near to the dynamical equator and equinox. I would like to point out that the two are not the same. Is the implication there? Do you read it that way? I mean, the FK5 certainly is trying to get onto the dynamical equator and equinox, but there will be some kind of error associated with that, and I just have a little concern.

Hughes:

I think that's in the phase, "as near as possible." I agree with what you say, that's exactly correct. We are really talking about two different animals here, yes. But the point is that the two are not so far apart.

Standish:

Then regarding an overriding philosophy; once the attempt is made by VLBI to get on to some system, it probably is a bad idea to try to keep attempting to juggle itself onto that system, and I think that's covered in the intended process.

Hughes:

Indeed, it is.

Standish:

I would say the same for the optical system and the dynamical system, that

it's better to stay in the system that you are most comfortable in, and then spend your efforts trying to realize what the ties are between them, as opposed to using the ties that you have kind of tentatively determined, and then forcing you onto a different system.

Hughes:

May I quote from note 4 of Recommendation VII? It says, "the directions of the coordinate axes should not be changed, even if at some later date the realization of the dynamical equinox or CEP are improved." I believe that's precisely your point.

Kovalevsky:

Well, first I say I agree with what Myles (Standish) says. This morning, in my presentation, I insisted on saying that it is a guideline and not necessarily an exact point at which you want to arrive. I mean it's a kind of objective that we will try to do, but once we decide upon a point, that will be it. Of course, the closer it is, the better it is, but that's all. Now I would like to answer also, a little bit, what Ken Johnston just said. It's true, and because he was just emphasizing what I said, that the milliarcsecond or tenth of a milliarcsecond reference frame in the optical is not for tomorrow and for the next generation. It doesn't mean that we shall not have to decide upon a first realization of this optical reference frame as soon as we are going to also adopt the VLBI one. This one, I guess, would rather be at the milliarcsecond or maybe two milliarcsecond level. It doesn't mean that we have to live with the FK5 until 2015 or 2020, but it's true that probably in 2020 we will have a better realization with stars.

Johnston:

I would like to make one further comment on Recommendation VI. One of the things that I see, and I consider it dangerous, is that we all make up catalogs and we actually then average all those catalogs together. I think today, the VLBI data that is taken can actually be put into a common data base. And I think that what we need to do in the recommendation, maybe we should reword it to say that, is that we urge all VLBI observers to take the data such that it can be put into into a common data base, so that in the future we can go back and reduce that data to a common system rather than be averaging one catalog against the other. I think that's a little old fashioned. We are at this point right now where we can actually go back to the original data, and as time goes on, that data will be more and more valuable. This gets into the business of the constants. We don't have to worry about what constants people are using and things of that nature. I think that's very important, and maybe that should be put into that recommendation.

Seidelmann:

I would like to suggest an editorial improvement, and that the request I made previously, that Recommendation VII have added in, both the statements of the FK5 equator and equinox and the dynamical equinox, so we don't, by implication in this recommendation, confuse people. One of the results of this whole process is going to be the requirement that people recognize the difference between catalog equinoxes and the dynamical coordinate system, and the requirement that we have the transformations from those systems to the extra

galactic system. So I think that it's a mistake to have the recommendation, at this point, implying that there isn't a distinction between the catalog and the dynamical equinox.

Hughes:

As I think we discussed between ourselves, it's not that there is anything wrong here, but it could be misinterpreted. That's your point. Here we have an expert like Myles (Standish) asking, "well wait a minute, what do you mean here?" So that goes to show you that it is a bit ambiguous. I don't think it's a major thing, but it's just these little things that cause trouble later on. What is eminently clear to every one in the room today is, of course, complete mud to somebody ten years later. Any other comments in this general area? Let me then ask, are there any general comments that one might wish to make about Recommendation VIII? That is, on the astronomical constants as presented by Dr. Fukushima this morning.

Fukushima:

Well, after the Virginia Beach meeting, I was reminded that Commission 5, concerned with astronomical data archiving and e-mail, and so on, should be involved with this new working group, and I and Jim Hughes already had contact with the president of Commission 5, George Wilkens, and the next president, Dr. Hauck, and I feel that their response is very positive, and if possible, I would like to propose adding one more number in the phrase saying, commission four and eight and such and such. I'd like to add one digit to say, four coma, five coma, eight and so on.

Hughes:

Any comments on that proposal? No? Then, I would like to conclude this portion of our discussions in the next ten or fifteen minutes, unless something comes up which requires more discussion, and save the last forty-five minutes or so for a meeting of the Working Group members who are in attendance here. I think the matters we would like to consider in the WG include two of the points that have been raised just now. Namely, adding something about distinguishing between the dynamical and catalog equinoxes, and the question of adding Commission 5, and maybe the general question of the working groups. You will recall that these recommendations involve the creation of two working groups. The proposed amendment to Recommendation V may also be considered. And finally, in the last moments here, we might discuss another topic which has been touched upon, that is, the question of implementation. Now we just had a discussion about the extra-galactic coordinate frame, and we understand that it is a long-term thing. It's not quite so clear in the case of time, in the earlier recommendations. That could, as I'm sure we can all appreciate, lead to some difficulties. On the one hand, I don't think there's any desire at this time, to mandate some date, in some legalistic way. On the other hand, perhaps something should be said about it. If we say nothing, well than everyone is left twisting slowly, slowly in the wind, as the saying goes. So, do we have to say something about the time frame for implementing new time scales? Ken (Seidelmann), since you brought this matter up, do you wish to amplify what you said?

Seidelmann:

The point I would make is that the recommendations all talk to something that should be changed in the future, with the exception of the time systems, and the question of how can you sell an organization on the benefit of making a change cannot be answered by just saying we are going to change the nomenclature of the time system. It can be sold on the basis that we have improved constants, we have an improved reference system, and we have improved time scales. So, I would recommend that somehow we make it clear that the implementation of these recommendations take place as a package when the reference system and the system of constants can be delineated.

Hughes:

Are you saying then, that we would somehow adopt these new time scales in a decade or two?

Seidelmann:

No, I think we've given a time limit of three years for the physical constants. From what I've seen today, while I agree with Ken Johnston that we are not going to have the ultimate extra-galactic source reference frame, I think its going to be a heck of a lot better than what we have right now. Maybe three years from now, Dr. Kovalevsky indicated three years from now he did not think it would be available, but I think three years from now we will be in a position to say, "here is the whole package, we recommend that it be implemented in the national ephemerides and for scientific purposes at the so-and-so date."

Hughes:

I would particularly ask that we address this question of a package deal. Is such any assistance? Are there any positive aspects to that approach?

Fliegel:

I'm not sure that I am prepared to address Ken's (Seidelmann) question in detail. I'd like to consider that issue. The point that I was raising here is that we know that by the end of this decade, we should have vastly improved nutation and precession values. I hope from lunar laser ranging, certainly from other techniques. We know that things are changing rapidly in the lunar laser ranging situation because we do need something like, what?, eighteen years of good data from that source, and although the lunar laser ranging sequence is almost that old, everyone knows that the early observations were very poor. Without going into other details here, I am sure that Ken could make the same point from VLBI and so on. We know that around the year 2000 we will be in a good position to change constants and deliver a new package. I really wanted to raise the question. Does anyone feel that by 1994, or even 1997, we should be delivering a whole new package of constants, knowing that the nutation and precession is still going to be subject to considerable improvement?

Johnston:

Well, let me just say there has to be something to aim at here. I think if one is going to adopt anything, we will have to adopt it as follows; saying, these constants and this reference frame are good to a certain level of accuracy, and maybe for 1994 our aim may be to go with a set of constants and

a reference frame and everything else that goes along with it, that's good to a milliarcsecond accuracy. And then after that, we'll add to that different accuracies, but that would give you something to aim at. You would say, "this frame we believe is good to this accuracy." Otherwise I don't know how we are going to implement it, because we'll be implementing different things at different times. So that may be one way of implementing it.

Hughes:

As far as the constants are concerned, part of the content of Recommendation VIII addresses precisely this point with the creation of a permanent working group.

McCarthy:

I wonder why we aren't adopting the constants right now, in fact the constants are being adopted. We can make all these resolutions and recommendations, but these constants are being used today by researchers in the field now. And by us fooling around until the year 2000, it just looks silly. We should be adopting all these things as rapidly as possible, and I see the only constraints would be the ephemerides. They would be the only reason to give some sort of lead time, and I think the only constraint of adopting it should be how fast could the ephemerides people get their act together to put it in place.

Hughes:

That's a fair comment. You just summed up, I think, some of the previous conversation when you weren't here. (NB Dr. McCarthy had just arrived due to travel delays.) That really is one of the major sticking points. This has been made abundantly clear. Do I hear any other comments?

Standish:

I think we have to consider the role of the IAU. Certainly there are a number of groups, VLBI, Lunar Laser Ranging, that for a number of years already have not been able to use the J2000 system. They've been using improved precession and improving nutation and everything else. And maybe we have to consider what we are doing when we send out constants. I don't think we can provide constants to some of these cutting-edge technologies. They are racing ahead of us as fast as we can catch up with them. Maybe the more important thing is, when somebody does something, there should be some kind of standard of archiving, what he has done and what he has used to do it. You know, if you are going to use a certain ephemeris or certain sub-routine, it has to be documented there. And if it's a new sub-routine that you have created to enable yourself to do your task, then it's somehow your responsibility to document and archive that fact. I don't know, we are at a funny place.

Hughes:

Well, I think we are just living in very fast moving times, as you say, but that's why Resolution VIII as written, is so important. From the very outset one of the fundamental tasks of that sub-group has been to try to come to grips with, what I call the "central dilemma," that is, "constants" on the one hand and "best current values" on the other.

Kaplan:

Perhaps, and I think Dr. Fukushima is thinking along these lines too, perhaps we should begin thinking about, rather than just a series of constants, a set of parameterized models. The parameters can be adjusted by these cutting-edge technologies, and everybody would know what those standardized parameters refer to, and in turn could use those improved parameters, feed them back into their own sub-routines, and effectively use them. I think Dr. Fukushima mentioned this morning how practically useless the precession constant is. It really doesn't appear in anybody's algorithms. What you need is some sort of transformation that enables you to propagate a change in the precession constant through the standard algorithms for the three fundamental precession angles, so that you can actually use improved values of the precession constant.

Fukushima:

That's a very good point, and unfortunately the other time we introduced the present system of constants, we had to wait eighty years to revise the nautical almanacs and astronomical almanacs, and the next time we should never have any delay. What that means is that we should prepare also a kind of, say planetary ephemeris or precession formula, at the same time we present the next system of constants. Because I quite strongly feel that the current changes in technology and the developments are so rapid that even every three years, I feel, are a little bit too long for some researchers.

Hughes:

We do indeed live in fast changing times, to our sorrow perhaps. Alright, we are getting close to the time when I thought we could terminate this general discussion, and I would ask members of the working group to remain so that we could consider some of these questions. I would imagine that we will have a great commonality in attendance with the people that were here today and the Joint Commission meeting scheduled for Monday afternoon. You will notice that this Joint Commission meeting I've been talking about does not appear on your program in the "official list" of Joint Commission meetings, but it does appear in the individual sponsoring Commissions' schedules. And it is none-the-less valid for appearing only there. So I would invite you all to meet once again on Monday afternoon. After a short break, the Working Group on Reference Systems will meet here.

Working Group on Reference Systems (WGRS) Meeting

Although neither formal minutes or voice recordings were taken for this meeting, the following notes by the Chairman are a fair representation of the results of the meeting.

The proposed alteration to Recommendation V was not accepted. Various minor changes and additions to the wording of some recommendations were accepted. These included: a clarification of dynamical vs catalog equinox, the wording of Recommendation V was changed from "TDB may still be used," to "TDB may be used," and an additional note was added to Recommendation IV. The latter was in response to a point raised by Dr. D.W. Allen and Prof. N. Ashby in correspondence with Prof. P. Paquet. These and the other minor changes may be checked by comparing the Recommendations (as printed in the Final Program

of the General Assembly or in the Proceedings of IAU Colloquium 127) with the adopted Resolutions printed in the *Proceedings* of the General Assembly.

A draft Recommendation X was approved which essentially suggested that implementing dates be prepared for presentation at the XXII General Assembly. The text is not given here since the proposal was subsequently defeated in the Joint Commission Meeting (JCM) of the sponsoring Commissions. This same meeting overwhelmingly approved the original recommendations (as amended) as Commission Resolutions. The Chairman of the WGRS forwarded the recommendations to the Resolutions Committee with the request that they be considered, if possible, as IAU Resolutions. This was accepted, and the Recommendations became IAU Resolutions by vote of the final General Assembly in Buenos Aires.

The adopted resolutions set up two working groups: 1) The Working Group on Astronomical Standards (WGAS) with Dr. Toshio Fukushima confirmed by the JCM as its chairman, and 2) The Working Group on Reference Frames with Dr. Christian de Veigt confirmed by the JCM as its chairman. Some members of these groups were appointed at the JCM, but the full membership list of these groups will be provided by the respective chairmen.

Submitted by:

James A. Hughes, Chairman and Editor