FORTUNE EIGHT

Aerospace Industries, Inc.

International Technical Services

Original Lecture: 2002 April 3

MEMORANDUM

To: CMA Class

From: Chauncey Uphoff

Subject: Class Notes for Lecture #11

In Lecture #11, I continued my discussion of the Main Problem of Artificial Satellite Theory from Lecture #10. I discussed the importance, to my understanding of the theory, of Izsak's note in the AJ (1963) and John Breakwell's hint to me to read that note so I could understand the transformation from osculating to mean elements in these theories. That was when the whole thing came alive to me. Before that, it was a semi-coherent muddle in my mind. I explained my question regarding the meaning of the expression "zero mean eccentricity." That was a great puzzlement to me for a long time. Only when I read Izsak's note (at Professor Breakwell's suggestion) did I "get it." CMA students, who wish to understand these important distinctions in the theory, are encouraged to read Professor Imre Izsak's important note in the AJ. (See my Kozsaks memo for Refs, or see below).

Before that discussion, I gave a somewhat disjoint description of your last homework assignment (last unless I change my mind). The students rebelled and said, "What are you asking us to do?" Those rebels were right to challenge me on not being explicit in my statement of homework requirements. I promised to make the homework requirements more explicit, and to get them to you, in writing, within one week. I warned the class that this will be a tough one because it requires the student to dig out the pertinent theory from the literature, to think about it, and to articulate it to me in a language I can understand (the language of Physics). I should hope to see lucid descriptions of the theory in terms of the important quantities I use, namely, Energy (per unit spacecraft mass), angular momentum (in the same nomenclature), position in the (mean or osculating) elliptical orbit described by the mean (or osculating) orbital elements, and the angular elements of the

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orbits, given with respect to an inertial (non-rotating) frame fixed to the center of mass of the central planet.

Now, let me explain the final homework assignment in a way that, I think, cannot be misinterpreted.

The final (Lecture) homework assignment:

1. Show that the variables (Hill's variables) used by Izsak in his 1963 note in the AJ form a canonically conjugate set. What advantage does the use of canonically conjugate variables have for the developers of perturbation theories? (See big Battin Chapter 10 or Brouwer & Clemence, Chapter ?).

2. Explain how Izsak describes the relationship between osculating elements and mean elements. Does it make sense to use the expression "zero mean eccentricity?" Discuss carefully.

3. What canonically conjugate set of variables does Brouwer use in his 1959 paper? How are the short periodic terms removed from the osculating disturbing function?

4. Describe the iteration procedure necessary to convert from osculating elements to Brouwer mean elements (with J_2 only). How was this iteration done in Kozsaks (KOZTST97.FOR)?

Here are the references from the KOZAKS memo: dig them out and understand them if you can. If you can't, don't worry about it; it took me 15 years to understand it. Note that there are some errors in the expressions for long-periodic terms (those that go as the agument of pericenter) in Brouwer's and Kozai's papers. They are algebraic errors (and typos) in the transformations back to Keplerian elements from the variables used in the perturbation theory. I also warned the students that these papers present a notational nightmare, for which Brouwer apologized, and corrected in a useful table, at the end of his paper.

REFERENCES

1. Kozai, Y. 1959 *Astron. J.* **64**, p 367.
2. Izsak, I. 1963 *ibid.* **68**, p 559.
3. Brouwer,D. 1959 *ibid*., **64**, p 378.
4. Hill, G.W. 1913, *ibid*. **27**, p 171.
5. Aksnes, K. 1972 *Astron.&Astrophys.*, **17**, p 70
6. Kozai, Y. 1962 *Astron. J.* **67**, p 446.

Later, I discussed the code (KOSTST97.FOR) and the methods implemented therein. The main part of this discussion was to explain the differences between the code I posted on the web-site and the code described in the KOZAKS memo. The 97 in KOSTST97 stands for the year in which I modified the code to include the mean elements from the Kozai/Izsak/Aksnes theories and the (J_2-only) Brouwer/Kozai mean elements on separate lines in the output. The first line in the ephemeris contains the osculating orbital elements, the second line contains the mean elements (including effects of J3 and J4), and the third line contains the Brouwer/Kozai mean elements (J_2-only). This third line is what should be entered into Johnny Kwok's LOP (later named POLOP) as mean elements when the KOZAKS iteration fails in later versions of LOP. (Somebody, not Johnny Kwok, "fixed" my original version when it "wuzn't broke"). If you have trouble converting from osculating to mean elements using POLOP, just use KOZAKS (with MNOSC = -3 or -4) and then enter the third line as "mean elements" into POLOP at the initial epoch. You'll have to convert mean true anomaly to mean mean anomaly (the vicious anomaly) for eccentric orbits but that's just Kepler's equation the easy way. I don't know which version (of the osculating to mean conversion) is embedded in STK but I shouldn't be surprised if it's "broke."

I reiterated that this "final" (Lecture) homework is something you'll have to work out for yourselves. I'm not going to lecture on it any more than I have done, so as to show you where to find what you need. Go for yourselves; then you'll understand it if you want to. But do not expect a roasted duck (game-bird) to fly into your mouth. Remember, Jason and Rodney assign the lab homework problems; there will be several more of those as you finish up your course project.

Best regards,

Chauncey Uphoff 2002 April 7