

THE DETERMINATION OF PARAMETER OF THE INTERIOR ORIENTATION OF
PHOTOGRAMMETRIC CAMERAS - A BIBLIOGRAPHY

Hartmut Ziemann
Photogrammetric Research
National Research Council
Ottawa, Ontario K1A 0R6
Canada
Commission I

ABSTRACT

A bibliography of papers dealing with various aspects of the determination of principal points and of lens distortion has been prepared. An attempt was made to obtain copies of all the included papers and cross-reference them. The project was carried out in support of and as a background for the revision of the ISPRS Commission I document "Recommended Procedures for Calibrating Photogrammetric Cameras and for Related Optical Tests". The paper explains the bibliography program used and includes a sample consisting of 23 entries.

INTRODUCTION

The "Recommended Procedures..." [Carman 1961] were developed in the years following the Second World War under the leadership of Dr. L.E. Howlett, the then president of ISP Commission I, with input from many different parties concerned. They reflect advances made during this war in the development of cameras for aerial photography. The document was adopted by the then International Society of Photogrammetry at the 1960 Congress in London. A major ammendment was made in 1972 with an addition dealing with MTF and OTF measurements.

A review of section 2 "Calibration" was recently carried out based on experiences in the U.S.A. and Canada [Tayman and Ziemann 1982]. This review lead the author to a search for publications relevant to the development of the "Recommended Procedures...". About one year ago, a change to a different computer system within the National Research Council (NRC) resulted in the availability of a bibliography program. NRC includes the Canadian Institute for Scientific and Tehcnical Information with extensive holdings in, for example, physics and engineering. A Photogrammetric Research Section was formed at NRC in 1951. This lead to the subscription to a variety of photogrammetric journals. Thus, it could be expected that most desired English-language publications could be located. In addition, many papers published in other-language photogrammetric journals after 1951 and a good selection of photogrammetric text books published after 1951 are available at NRC.

The paper gives a short description of the most relevant features of the bibliography program and presents a sample set of papers included in the bibliography.

THE BIBLIOGRAPHY PROGRAMS PACKAGE

The used programs are under development in the Division of Physics of NRC. The author is one of the first users. The biliography base program permits the development of individual "menus" in that the user is able, within established general guidelines, to decide the kind of data to be entered, the order of their entry in record fields and the naming of the fields. The data are stored in the order of entry in a bibliography file, and the fields of

Table 1	A:	1	AU	M	Author	!Author(s)
	T:	4	00	S	Title	!Title
	F:	7	00	S	Format	!Format of presentation (see RECORD 2)
	J:	8	00	S	Journal	!Publication reference
	D:	9	DA	S	Date	!Date of publication (yyymmdd - prompted)
	M:	10	00	S	Media	!Type of available copy (see RECORD 3)
	K:	3	00	M	Keyword	!Keyword(s)
	L:	11	00	S	Language	!Language of publication (see RECORD 4)
	I:	2	00	M	Class.	!Classification (see RECORD 5)
	C:	14	00	M	Summary	!Abstract(s)
	N:	12	00	M	Notes	!Notes
	#:	5	00	S	Acqu.cd.	!Acquisition code (yyymmdd.i)
	?:	14	00	S	No.ref.	!Number of cited references
	>:	13	00	M	Point >	!Points to a cited reference by acqu.no.
	<:	15	00	M	Point <	!This item is cited in (acqu.no.)
	P:	6	00	M	Location	!Storage location (see RECORD 6)
	!:					! a database of photogrammetric references

each record can be resorted prior to editing operations. Searches are carried out on editing files. A header record contains all data needed by the program. The header record can be individually formulated to meet the user's needs. Table 1 shows as first record the header record chosen by the author. It contains from left to right within each field

- a one-character field identification symbol
- the position of the field in the record after resorting for editing and searching
- a two-character symbol identifying the type of prompt desired during the addition of records to the bibliography file
- M or S to identify multiple use of a field identifier versus enforced single use
- a field name (see Table 3)
- a field description

The order of fields in the header file determines the order in which data will be prompted during entry when the bibliography program is used. Records 2 to 6 (Table 2) show abbreviated symbols used by the author for the contents of some fields in an effort to limit the overall record length.

Table 2	RECORD	2
	Notes :	Format of presentation (if not an article)
	Notes :	BOOK - Text, thesis, handbook, etc.
	Notes :	PROC - Proceedings of a conference, symposium, etc.
	Notes :	NORM - Standards
	Notes :	REPORT - Internally published results
	Notes :	MEET - Meeting notices
	Notes :	LECT - Lecture manuscripts
	Notes :	PROP - Research proposals
	Notes :	CORR - Correspondence
	Notes :	LIST - Mailing lists, etc.
	Notes :	BIBL - Bibliographies
	Notes :	BROC - Technical or sales brochures, etc.
	Notes :	MANUAL - Manuals, user's guides, etc.
	Notes :	CATAL - Catalogues
	Notes :	DATA - Experimental data
	Notes :	NOTE - My notes
	Notes :	PAT - Patents
	Notes :	SPEC - Specifications

	RECORD	3
	Notes :	Media (if not a xerox copy)
	Notes :	O - Original journal or book copy
	Notes :	R - Reprint
	Notes :	P - Photographic print
	Notes :	S - Slide
	Notes :	V - Viewgraph
	Notes :	M - Microfiche
	Notes :	F - Floppy disc
	Notes :	T - Magnetic tape
	Notes :	D - Drawings

Table 2
(cont.)

RECORD	4
Notes :	Lansuage
Notes :	E - English
Notes :	F - French
Notes :	D - German
Notes :	R - Russian
Notes :	J - Japanese
RECORD	5
Notes :	Classification (n is a 1- to 3-digit number, L a letter)
Notes :	UDCn.n.n.n;n.n.n.n - Universal decimal classification
Notes :	CISTI-LLn.n-Ln - CISTI reference number
RECORD	6
Notes :	Storage location of item
Notes :	SHELF - On bookshelves (unspecified)
Notes :	HOME - At home
Notes :	BINDiii - In specified binder
Notes :	PANiiii - In specified panbox
Notes :	CABiiii - In specified file cabinet drawer
Notes :	000 - Haven't sot it yet (but aware it exists)
Notes :	? - Lost, misplaced, ...
Notes :	! - Loaned (append borrower's I.D.)
Notes :	-----

Tables 3 to 5 list the same record - the approved "Recommended Procedures..." in three different ways:

- as a record of a bibliography base file (Table 3)
- as a record of a bibliography prepared for editing (Table 4)
- as a record of a editing data set (Table 5)

Table 3	Author :	Carman,P.D
	Title :	Recommended Procedures for Calibrating Photogrammetric Cameras and For Related Optical Tests
	Format :	REPORT
	Journal :	Div. of Physics, NRC, Sept. 1964
	Date :	1961
	Media :	R
	Keyword :	NRC Optics
	Keyword :	ISP 1960 London
	Keyword :	Int.Or.
	Lansuage :	E
	Notes :	first published in Int.Arch.Phot.13,Part 4
	Notes :	rn00163
	Acqu.cd. :	019
	No.ref. :	3
	Point > :	009
	Location :	CAB1401

Table 5

A:	Carman,P.D
K:	NRC Optics
K:	ISP 1960 London
K:	Int.Or.
T:	Recommended Procedures for Calibrating Photogrammetric Cameras and For Related Optical Tests
#:	1017
F:	CAB1401
F:	REPORT
J:	Div. of Physics, NRC, Sept. 1964
D:	19610000
M:	R
L:	E
N:	first published in Int.Arch.Phot.13,Part 4
N:	rn00163
>:	021
?:	3

Table 4 RECORD 20

```

1 A: Carman,P.D
2 K: NRC Optics
3 K: ISP 1960 London
4 K: Int.Or.
5 T: Recommended Procedures for Calibrating Photogrammetric Cameras and For
    Related Optical Tests
6 #: 019
7 P: CAP1401
8 F: REPORT
9 J: Div. of Physics, NRC, Sect. 1964
10 D: 19610000
11 M: R
12 L: E
13 N: first published in Int.Arch.Phot.13:Part 4
14 N: no00163
15 >: 009
16 ?: 3

```

The sequence of the fields in the record shown in Table 3 corresponds to the sequence of entry, the sequence of the fields of other two records to that defined in the header record (see Table 1). The sequence of the fields should be chosen such that the fields appear in the sequence of frequency of their use for searches. Editing the file as editing data set has proven to be most efficient with the availability of an editor with keypad editing functions. A routine is available as part of the bibliography program package which permits ready conversion from a bibliography base file to an editing data file and vice versa.

The bibliography program prompts for its functions which include amongst others ADD, EXIT, FIND, KEY, MERGE, PRINT, PULL and SAVE. Most of these are well described by their name. The search routine FIND can be used to locate items by a combination of fields and character strings within fields. FIND creates an auxiliary data file which can be SAVED or PULLED for later use, or MERGED with another file. KEY can be used to alphabetically list all entries a certain field with the frequency of their occurrence.

A SAMPLE SET

The FIND and SAVE routines were used to extract from the author's data base all entries identified by the keywords "NRC Optics" and "Int.Or." which signify that the respective entry is a contribution to the subject area "Interior Orientation" by an NRC staff member associated with optical activities within NRC. The Photogrammetric Research Section does not administratively fall into this category. A full list of all pulled records is given as Appendix. The entries were sorted into chronological order. The original acquisition codes were replaced by 3-digit consecutive numbers to increase the interpretability of the sample set. All papers in this set were referenced by backward pointers (>: cited references) and forward pointers (<: use as a reference in a later paper). Backward and forward pointers are being placed on all entries into the data base. An asterick behind the number of references indicates that all references for this record have been included into the data base.

The KEY routine identified the following authors in the sample set:

```

3 brown,h
16 carman,p,d
1 corten,f,l,j,h
2 cruset,j
1 david,r
4 field,r,h
6 howlett,l,e
1 jackson,k,b
1 others,

```

Brown, Carman, Field and Howlett are former NRC staff members, the others appear in the selected records as co-authors only. The same routine identifies the following key words and, as before, the frequency of their occurrence

*** ENTRIES IN FIELD - Keyword - ***

23 int.or.
 3 is# 1952 washinton
 2 is# 1956 stockholm
 2 is# 1960 london
 1 is# ws i/2
 23 nrc optics

Finally, the routine was used to check the cross referencing. It found 35 entries pointing either way.

*** ENTRIES IN FIELD - Point > - ***

2 001
 1 002
 4 003
 1 004
 3 005
 4 006
 1 007
 6 009
 5 013
 5 014
 2 021
 1 022

*** ENTRIES IN FIELD - Point < - ***

2 003
 1 004
 2 007
 1 008
 1 010
 1 011
 3 012
 2 014
 2 015
 1 017
 1 018
 1 019
 1 020
 5 021
 5 022
 6 023

CONCLUSION

The features described for the short file presented in the Appendix apply for the author's bibliography base file throughout. A bibliography with several hundred entries of records related to the determination of the parameters defining the geometric-optical performance of an aerial cameras and covering items such as

- the definition of fiducial centre, principal point of autocollimation, point of best symmetry and other "principal points"
- the determination of equivalent, calibrated and back focal lengths and
- the determination of rotationally symmetrical and decentring lens distortion

is available from the author at the following mailing address

Photogrammetric Research
 National Research Council
 M-36, Room 4
 Ottawa, Canada K1A 0R6

It is intended to systematically extend the bibliography file by areas of interest to the author such as film deformation, reseau photography, image quality determination and specifications.

REFERENCES

- Carman, P.D., 1961. Recommended Procedures for Calibrating Photogrammetric Cameras and for Related Optical Tests.
International Archives of Photogrammetry 13, Part 4.
- Tayman, W.P. and H. Ziemann, 1982. Photogrammetric Camera Calibration,
International Archives of Photogrammetry 24, Part 1: 89-101.

APPENDIX

A:Field,R,H	A:Field,R,H
K:NRC Optics	K:NRC Optics
K:Int.Or.	K:Int.Or.
T:A Determination of the Distortion in a Number	T:A Device for Locating the Principal Point
of Air Camera Lenses	Markers of Air Cameras
#:001	#:005
P:CAB1401	P:CAB1401
J:Can.J.Res.10:239-243	J:Can.Surv.10(1):17-21
D:19340200	D:19490700
L:E	L:E
N:rn00096	N:rn00121
?:2	?:0 *
<:003	<:021
<:004	<:022
	<:023
A:Field,R,H	A:Carman,P,D
K:NRC Optics	K:NRC Optics
K:Int.Or.	K:Int.Or.
T:The First Air Camera Calibration in Canada	T:Photogrammetric Errors from Camera Lens
#:002	Decentering
P:CAB1401	#:006
J:Can.Surv.8(5):24-25	P:CAB1401
D:19440700	J:J.Opt.Soc.Am.39:951-954
L:E	D:19491100
N:rn00105	M:R
?:0 *	L:E
<:003	N:rn00124
	?:3
A:Field,R,H	<:007
K:NRC Optics	<:008
K:Int.Or.	<:009
T:The Calibration of Air Cameras in Canada	<:012
#:003	<:021
P:CAB1401	
J:Phot.Eng.12:142-146	A:Howlett,L,E
D:19460600	K:NRC Optics
L:E	K:Int.Or.
N:rn00109	T:Resolution, Distortion and Calibration of Air
>:001	Survey Equipment
>:002	#:007
?:3	P:CAB1401
<:012	J:Phot.Eng.16:41-46
<:021	D:19500300
<:022	M:R
<:023	L:E
	N:rn00126
A:Howlett,L,E	>:004
K:NRC Optics	>:006
K:Int.Or.	?:3
T:Photography for Survey Purposes	<:012
#:004	
P:CAB1401	
J:Phot.Eng.14:326-347	
D:19480900	
M:R	
L:E	
N:rn00116	
>:001	
?:13	
<:007	

A:Carman,P.D
 K:NRC Optics
 K:Int.Or.
 T:Some Requirements for Aerial Survey Cameras
 #:008
 P:CAB1401
 J:Can.Surv.11(6):3-12
 D:19531000
 M:R
 L:E
 N:rn00141
 >:006
 ?;4

A:Howlett,L.E
 A:Carman,P.D
 K:Int.Or.
 K:ISP 1952 Washington
 K:NRC Optics
 T:Specification of Methods of Calibrating
 Photogrammetric Cameras and Measuring their
 Resolution, Image Illumination and Veilins
 Glare
 #:009
 P:CAB1401
 J:Int.Arch.Phot.11, Part 1:(109)-(120)
 D:19540000
 L:E
 N:Part of the report on 2nd Plenary Session held
 1952-09-13 without identification of authors.
 Comm. I resolutions are on pp.(108)-(109)
 N:rn00464
 ?;5
 <:010
 <:011
 <:014
 <:015
 <:019
 <:020

A:Howlett,L.E
 A:Corten,F.L.J.H
 A:Cruset,J
 A:Carman,P.D
 A:Others,
 K:ISP 1952 Washington
 K:NRC Optics
 K:Int.Or.
 T:Discussions, ISP Comm. I
 #:010
 P:CAB1401
 F:PROC
 J:Int.Arch.Phot.11,Part 1:(108),(109),(201)-(218)
 D:19540100
 L:E
 N:rn00144
 >:009
 ?;25

A:Howlett,L.E
 A:Carman,P.D
 K:Int.Or.
 K:NRC Optics
 T:Specification of Methods of Calibrating
 Photogrammetric Cameras and Measuring their
 Resolution, Image Illumination and Veilins
 Glare
 #:011
 P:CAB1401
 J:Phis.10:85-93
 D:19540201
 L:E
 N:French text:123-133
 N:rn00484
 >:009
 ?;7

A:Carman,P.D
 K:NRC Optics
 K:ISP 1952 Washington
 K:Int.Or.
 T:Report of Commission I - Photography and
 Navigation
 #:012
 P:CAB1401
 J:Int.Arch.Phot.11,Part 1:3-55
 D:19540900
 M:R
 L:E
 N:rn00142
 >:003
 >:006
 >:007
 ?;27

A:Carman,P.D
 K:NRC Optics
 K:Int.Or.
 T:Control and Interferometric Measurement of
 Plate Flatness
 #:013
 P:CAB1401
 J:J.Opt.Soc.Am.45:1009-1010
 D:19551200
 M:R
 L:E
 N:rn00148
 ?;2
 <:014
 <:017
 <:021
 <:022
 <:023

A:Carman,P.D
 A:Brown,H
 K:NRC Optics
 K:Int.Or.
 K:ISP 1956 Stockholm
 T:Differences between Visual and Photographic
 Calibrations of Air Survey Cameras
 #:014
 P:CAB1401
 J:Phot.Eng.22:623-626
 D:19560900
 M:R
 L:E
 N:See #013 for oral introduction
 N:Also in Int.Arch.Phot.12, Part 4a
 N:rn00151
 >:009
 >:013
 ?;2 *
 <:015
 <:018
 <:021
 <:022
 <:023

A:Cruset,J
 A:Howlett,L.E
 A:Jackson,K.B
 K:ISP 1956 Stockholm
 K:NRC Optics
 K:Int.Or.
 T:Discussions: ISP Comm. I
 #:015
 P:CAB1401
 F:PROC
 J:Int.Arch.Phot.12,Part 1:107-146,161+162
 D:19570100
 L:E, F, D
 N:rn00152
 >:009
 >:014
 ? :22

A:Carman,P.D
 K:NRC Optics
 K:Int.Or.
 T:Camera Geometry in Photogrammetry
 #:016
 P:CAB1401
 J:Phot.Rec.2:455-456
 D:19581000
 L:E
 N:rn00202
 ? :2

A:Carman,P.D
 K:NRC Optics
 K:Int.Or.
 T:Camera Calibration in Five Man-Hours
 #:017
 P:CAB1401
 J:Phot.Rec.2:454
 D:19581000
 L:E
 N:rn00562
 >:013
 ? :4

A:Carman,P.D
 K:NRC Optics
 K:Int.Or.
 T:Commission I - Photography and Navigation
 #:018
 P:CAB1401
 J:Can.Surv.15:172-177
 D:19600500
 M:R
 L:E
 N:also in Int.Arch.Phot.13,Part 3
 N:rn00156
 >:014
 ? :1 *

A:Carman,P.D
 K:NRC Optics
 K:ISP 1960 London
 K:Int.Or.
 T:Recommended Procedures for Calibrating
 Photogrammetric Cameras and For Related
 Optical Tests
 #:019
 P:CAB1401
 F:REPORT
 J:Div. of Physics, NRC, Sect. 1964
 D:19610000
 M:R
 L:E
 N:first published in Int.Arch.Phot.13,Part 4
 N:rn00163
 >:009
 ? :3

A:David,R
 A:Carman,P.D
 K:ISP 1960 London
 K:NRC Optics
 K:Int.Or.
 T:Discussion: ISP Comm. I
 #:020
 P:CAB1401
 F:PROC
 J:Int.Arch.Phot.13,Part 4:54-58
 D:19610100
 L:E
 N:rn00157
 >:009
 ? :5

A:Carman,P.D
 A:Brown,H
 K:NRC Optics
 K:Int.Or.
 T:Camera Calibration in Canada
 #:021
 P:CAB1401
 J:Can.Surv.15:425-439
 D:19610500
 M:R
 L:E
 N:rn00158
 >:003
 >:005
 >:006
 >:013
 >:014
 ? :10
 <:022
 <:023

A:Carman,P.D
 K:NRC Optics
 K:Int.Or.
 T:Camera Calibration Laboratory at N.R.C.
 #:022
 P:CAB1401
 J:Phot.Eng.35:372-376
 D:19690400
 M:R
 L:E
 N:rn00169
 >:003
 >:005
 >:013
 >:014
 >:021
 ? :6
 <:023

A:Carman,P.D
 A:Brown,H
 K:NRC Optics
 K:ISP WG I/2
 K:Int.Or.
 T:The NRC Camera Calibrator
 #:023
 P:CAB1401
 J:Phis.34:147-165
 D:19780700
 M:R
 L:E
 N:rn00177
 >:003
 >:005
 >:013
 >:014
 >:021
 >:022
 ? :7