The History and Future of the Five String Cello

5弦チェロの歴史と将来

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THE HISTORY AND FUTURE OF THE FIVE STRING CELLO

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I: J. S. BACH AND THE FIVE STRING CELLO

It is now almost three hundred years since Bach composed his six suites BWV 1007 – 1012 and still there are many open questions about them. Especially the problem which instrument to use in order to perform them properly is not really solved. Since their re-discovery in the beginning of the 20th century it was assumed that they were written for the Stradivari-type four string cello that had by then replaced its predecessors. Playing them on this type of cello however results in major technical difficulties already in the 3rd suite: In the Prélude of that suite the use of the thumb is necessary, a technique that was not in use yet at Bach's life time. The most problematic suite however is the 6th which presents extreme difficulties if played on a four string cello because of the frequently requested high registers. Bach composed several other works for solo instruments but they do not show any similar examples of such outstanding technical demands. That is why in the recent past some musicians and historians started to doubt that the Stradivari cello was the instrument Bach wrote the six suites BWV 1007-1012 for. Their position is based on the following facts and conclusions:

- The cello of Bach's time is defined by historians as an instrument resembling a big viola[1] *(see pictures 1 and 2)*, being held under the chin, across the body and later between the knees[2]. *(See picture 3.)* It was originally intended to assist the double bass as an accompanying bass instrument and came in various sizes and tunings. Due to the longer strings the player's left hand could cover a significantly smaller tonal range than it could cover using a violin.

Picture 1: A violoncello da spalla,, placed behind a violin. [*This picture was taken from the Internet. If there are any copyright issues please contact clemens.doll2 ATgmail.com.*]

1 Johann Mattheson: *Das Neu-Eröffnete Orchestre* (1714) " *The violoncello, the bass-viola, the viola da spalla are small bass- violins with 5 and 6 strings*."

2 J.G. Kastner; Traité Général D'instrumentation (1834): "*VIOLA DA SPALLA (shoulder viola) - There is no information on the way that this instrument was tuned; It was suspended from the right shoulder with a ribbon. It is to be presumed that the viola da spalla was an approximate equivalent to our current violoncello, because one still finds village musicians who suspend the violoncello from the right shoulder with a strap,* ***whereas our artists hold it between the knees****"*

Picture 2: A modern replica of a viola da spalla, about the same size as the violoncello da spalla. Both instruments are arm-held. [*This picture was taken from the Internet. If there are any copyright issues please contact clemens.doll2ATgmail.com*.]

Picture 3: A violoncello piccolo *(possession of the Musashino Instrument Museum; made by A. Gragnani ca. 1785 in Livorno)* compared to a 4/4 cello.

- The first five suites for cello, obviously intended for a four string instrument, are somehow untypical in their structures compared to Bach's usual sophisticated technique of composition: they are much plainer and less intricate than for example the violin partitas and sonatas. The sixth suite however, which calls for the use of a five string instrument[3], is the first one among the cello suites that equals the complexity and beauty of the violin sonatas and

[3] Anna Magdalena wrote before the Prélude: "*a cinque cordes*" (for five strings) and added the notation C, G, D, a, e'; not specifying any particular instrument:

partitas.

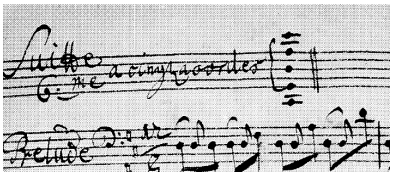
- Bach owned and occasionally composed for a five string, arm-held instrument, called *viola pomposa*[4], which he himself used to call *violoncello piccolo*[5]. It featured the usual low tonal range of a cello but the fifth string gave access to an additional tonal range almost as high as a violin's. (T*he 'modern' violoncello piccolo used today, for example in some of Bach's cantatas, is mainly built as a knee-held instrument.*)
- The four string Stradivari-type cello in its present size and way of holding established itself at the end of the 18th century[6], more than three decades after Bach wrote the cello suites, and in a time when Bach and his work was already almost forgotten.
- It is very unlikely that Bach intended to use two completely different types of instruments, a big Stradivari-type and a small, chin-held viola-cello, for the same cycle. Bach was a cembalist but also a violin and viola player, which means he could play the viola pomposa. There is no mention of him having played the cello. It is very unlikely that he switched within one cycle between instruments he was familiar with and instruments he wasn't.
- Playing all suites on any four string cello would result in a reasonable increase of technical difficulties proceeding from the 1st to the 5th suite[7] but proceeding to the 6th would present a sudden, grotesque rise to a level of difficulty that the cello repertoire only reached and dealt with more than fifty years later.[8]

At this point the following conclusion can be drawn:

- Bach started to compose his cello suites for a viola-like four string cello, not for a knee-held, big, four string cello.
- For the 6th suite Bach used a five string, arm-held instrument.[9] The style of composition changed dramatically - the piece became as complicated and intricate as the violin sonatas and partitas. After discovering the possibilities of this five string instrument there would have been no reason to return to a four string one.

The obvious questions are why this five string viola-cello did not survive him and why the cello didn't evolve to become a five string instrument.

Around the time when Bach composed the cello suites the Italian violin makers Stradivari, Montagnana and Goffriller decided the modern cello's acoustically optimal final shape and size.



4 J.G. Kastner; Traité Général D'instrumentation : "*VIOLA POMPOSA - This instrument was invented by the famous Johann Sebastian Bach. It was taller and higher than the ordinary viola, but it was held it in the same position as the viola; it had a fifth string in addition to the four strings of the viola, tuned to E […]. As the violoncello was being perfected little by little […] the viola pomposa was […] easily forgotten since it was heavy, and thus, inconvenient to manipulate.*"

5 This habit of Bach must have been t be the reason for all of the later misunderstandings of the title 'Suiten für Violoncello': Bach's 'violoncello' of choice for the sixth suite was actually a viola-cello, most likely the viola pomposa, an arm-held big viola, very similar or identical to the violoncello da spalla (Picture 1, and not a small version of a Stradivari-type violoncello.

6 Leopold Mozart; Versuch einer gründlichen Violinschule; 1787; *"Nowadays the violoncello […] is held between the legs, and one can justly call it […] a leg-fiddle."*

7 In the suites I to V the tonal range does not require the use of any other clef than the bass-clef.

8 In Anna Magdalena's copy already in measure 9 of the Prélude the high notes make the use of the C-clef necessary; interestingly in its alto version, which usually is used for viola and viola da gamba.

9 Klaus Marx; Die Entwicklung des Violoncells und seiner Spieltechnik bis J.L.Duport. On page 52 Marx states that the sixth suite was written for "a flat instrument, held like a violin and tuned C G d a e1".

Picture 4: A Stradivari four string cello. [*This picture was taken from the Internet. If there are any copyright issues please contact clemens.doll2 ATgmail.com.*]

It has almost exact the violin's proportions, enlarged by the factor of two. Like the violin it also had four strings. Since it was much bigger than the viola-cellos it had to be held between the knees. It could produce a bigger sound than all other cellos which is the reason why it slowly displaced its smaller relatives. Its longer strings resulted in a smaller tonal range than a viola-cello's, but that wasn't a major problem because of the role of the cello as a mere bass instrument at that time; there was no need to play very high or fast notes.

When this new cello had established itself at the end of the 18th century Bach (1685 – 1750) was dead and his music already was almost forgotten until the beginning of the 19th century and Felix Mendelssohn Bartholdy's (1809-1847) re-discovery of Bach's works. The problem of playing the suites on a big four string cello never presented itself during Baroque and early Classic: The cello suites had never really been introduced to the public until the beginning of the 20th century. By then the choice of instrument was never even questioned: the 'cello' (or cellos) Bach wrote the suites for was, wrongly, understood as the violoncello everyone used by then. The viola pomposa, the violoncello piccolo and other viola-cello models were long forgotten and out of use. Cellists nowadays still mostly think Bach's cello was of the same size and type as the cello they now use.

Beginning with Haydn and Beethoven, composers started to realize the possibilities of the Stradivari-type cello as a tenor instrument and the technical demands on the cello player started to rise because of the more frequent presence of high notes. The cello's job of doubling the bass changed and it started to become a rival to the violin; just like Bach seemed to have it planned with 'his' cello. The tonal demands expanded and cellists like Salvatore Lanzetti[10], the Duport brothers[11] and Bernhard Romberg[12] searched for ways to deal with this new role and the increasing technical difficulties. (*See Appendix B for a students' tree of B. Romberg and J.L. Duport..*) They came up with the idea of using the left thumb as a playing finger in high passages. Using the thumb as a playing finger is actually not the way how a cello (or any other string instruments) was intended to be played: If the thumb leaves the neck the fingers lose the necessary counter pressure needed to push the string down easily and properly. But introducing that rather awkward way of playing the cello seemed to have been preferable to an evolution of the treasured Stradivari-model cello to a five-stringed instrument

Stradivari must have been aware of his cello's limited tonal range: A violin player's left hand can cover the interval of a fifth in low positions, in high positions even more. A cellist's hand only can cover a fourth, which results in the more frequent need of position changes. The thicker strings of a cello also request the use of more pressure from the left and right hand than is necessary for playing the violin. The cello bow is shorter than a violin's; proportionally enlarged it should

10 Salvatore Lanzetti (1710-1780), Italian cello virtuoso and composer; Lanzetti is said to have bee n one of the first cellists to use the left thumb as a playing finger.

11 Jean-Pierre Duport (1741-1818) and Jean-Louis Duport (1749–1819), French cello virtuosos and composers

12 Bernhard Romberg (1767–1841), German cello virtuoso and composer

actually be much longer. All these factors result in a greater difficulty to execute fast passages, long slurs and high notes.

But Stradivari probably stuck to the principle of four strings because of the good sound properties and because the role of the cello didn't require playing high notes yet. Nonetheless, there were some cellists who picked up Bach's proposition of using a five string instrument. Almost none of those instruments survived but they still can be seen depicted in drawings and oil paintings; some few can be seen in museums. The Musashino Academia Musicae Instrument Museum owns a relatively recently built Stradivari-size five string cello *(See picture 5.)*; a fortunate coincidence, because its existence proves that there was a continuous interest in using such an instrument. It is an Italian instrument, built by Vincenzo Postiglione in 1880. It has basically the same measurements as the Stradivari four string models, only the bridge is slightly wider because of the additional string. It would be very interesting to hear its sound, but it would be too risky to equip this antique instrument with modern strings.

Picture 5: The Postiglione five string cello.

Since there are almost no old playable instruments available anymore recently some few cellists in Europe and America started to use new, full-sized, five string master-made cellos for playing Bach's sixth suite[13]. However, the number of such cellists still is very small and there is no wide-spread documentation available about construction, sound and usability of their instruments. There are CD recordings featuring five string cellos, but since those are studio recordings they cannot deliver any conclusive data about actual sound properties.

The problems of Bach's suites and the general difficulty of playing the cello are still being widely ignored. Bach's 6th suite is now quite often being performed by viola - and violin players using contemporary copies of Bach's viola-cellos[14], but cellists still seem to believe they have to struggle on an instrument the work never was meant for.

A few cellists managed to master the 6th suite somehow on a four string cello. However, the question remains why so few cellists take the obvious choice and use a five-stringed instrument.

The only reasonable possible objection against the use of a five string cello could be an acoustic disadvantage compared

[13] One of them is the German cellist Joachim Schiefer, who provided us – together with the violin maker Thorsten Theis - with very valuable information about their five string cello. You can find his homepage in the link section.

[14] Mostly the *Viola da Spalla*. See: http://badiarovviolins.com/PDF/GSJ60_121-145_Badiarov.pdf

to a four string cello. Because of the presence of an additional fifth string there will be the need for a bigger bridge, a broader fingerboard, a thicker neck and a bigger tailpiece. Those changes will probably cause some loss of vibration of the body and thus lead to some loss of volume. The overtones of the additional string will possibly make up for some of that loss, but it is impossible to tell without trying and comparing.

In Japan it is presently impossible to do such research because there are no five string cellos available that could be compared to a high-class four string cello. The old ones are in museums and are not built to be equipped with modern strings. The new, five string cellos available on the market are either cheap, mass-produced factory instruments or 'electric' cellos[15], used in Rock- and Pop-music.

CONCLUSIONS:

- The optimal choice for a proper performance of Bach's 6th cello suite would be using a viola-like instrument, a choice that is not an option for a cello player.[16]
- For a cellist a five string cello would be the obvious choice for the performance of Bach's 6th cello suite[17]. A five string cello also would greatly facilitate the execution of the Sonatas BWV 1027-1029 on a cello (*originally intended for a 5- or 6 string viola da gamba*) and various Baroque- and early Classic concertos and sonatas.
- Further research would concentrate on comparing the sound properties of four- and five string cellos and the possible use of a five string cello for playing compositions of classic and romantic repertoire.
- There are very few high-quality five string cellos available for research in Japan.

These conclusions led us to the project that we hoped to get support for:

BUILDING A FIVE STRING CELLO AND TESTING ITS PROPERTIES.

Fortunately the project was approved in April 2013 and the following report will show the proceedings during the next three years.

THE TEAM

While working on the applying procedures, Doll and Yamazaki had already started talking to the violin maker Yoshio Ueda, who owns the shop 'Ekoda Strings' in Nerima/Tokyo, about taking the part of constructing the instrument. He agreed to start working on the project, beginning in April 2013

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15 Those instruments have no sounding body- the vibration of the bridge is being transported directly to an electric amplifier.

16 Some violin and viola players have recently started to play the suites on replicas of the violoncello- or viola da spalla, a cello-like, five-stringed instrument that hangs on a strap around the player's neck. That is not an option available to a cellist.

17 In 1981 the German musicologist Werner Grützbach wrote in his book *Stil und Spielprobleme bei der Interpretation der 6 Suiten für Violoncello von J.S.Bach*: "If a normal cello would be equipped with a fifth string an original performance of the 6th suite would be possible. Some cellists already did so successfully."

II. START OF THE PROJECT

- **MEETING WITH UEDA** [1]. *(April 5th 2013.)*

After the project was approved on April 4th the team started discussing the schedule of proceeding.
It was decided to construct at least one prototype of a five string cello in order to learn about basic sound- and handling properties.

Construction of PROTOTYPE I was begun on April 5th and the instrument was ready for first testing on April 15th.

PROTOTYPE I

CONSTRUCTION

Construction started on April 5th, converting an existent, low-price four string body to a five string cello. The instrument in question is a 4/4 *(= full sized, 750mm body length; distance from nut to bridge: 680 mm)* cello, presumably Check-made around 40 years ago. Equipped strings are: C-string: Spirocore (Tungsten[18]); G-string: Larsen (Tungsten); D, A- and E-string[19]: Larsen. A special tail piece was manufactured by Ueda that can accommodate five strings and adjusters *(Pictures 6 and 12)*.

The fingerboard was removed and replaced by a modified bass fingerboard. As seen, it is slightly protruding over the original neck *(Picture 7)*.

A new bridge was constructed, featuring a broader head in order to accommodate five strings in roughly the same distance from each other than on a four string bridge. The feet have the same spacing and placing as a bridge on a four string cello *(Picture 8)*.

An additional hole was drilled into the upper part of the peg box and a fifth peg was inserted. *(Picture 9. Picture 10* shows the process of drilling a hole into the peg box. *Picture 11* shows the filled holes of a 4-stringed cello's peg box. This procedure is necessary because the additional fifth string calls for a repositioning of the peg holes.*)* No internal changes were performed.

Picture 6

Picture 7

Picture 8

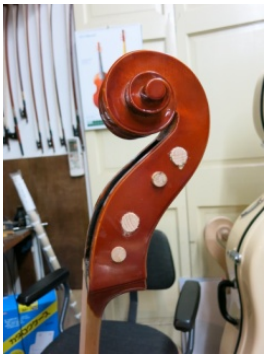
Picture 9

Picture 10

Picture 11

18 Tungsten is a strong (and quite expensive) metal that allows the production of strings thinner than the usually used steel versions. Thinner strings reduce pressure on the instrument's body which results in easier response and bigger sound volume.

19 Three main string manufactures (*Larsen, Jargar, Helicore*) some years ago started manufacturing and selling cello E-strings. They are rather expensive but are easily available in Europe and America. In Japanese dealers' string catalogues cello E-strings still do not appear.



TEST RESULTS [1]

SOUND QUALITY

The first sound-test results were actually rather disappointing.

- The E-string, when used as an open string and in the low positions, has a 'nasal' quality, rather different from the other strings' sound quality and somehow resembling a viola da gamba's or a treble's sound. *(It is a surprising facts that a violin's E-string is even thinner than a cello's but has no nasal sound at all.)* However, from the 4th position upwards the E-string produces a clearer and louder sound than the A-string does for the same notes.
- The A-string has a more muted quality than a comparable four string cello's A-string has.
- Both D- and G-string respond not very well above the third position.
- C-string shows no major changes compared to a four string cello's C-string.
- There is a quite strong 'wolf' on all Fs.[20]

Overall there is a certain loss of volume noticeable when the Prototype I is compared to a four string cello of similar quality level. How far this was inherent in the instrument or caused by the conversion is difficult to tell. In order to clear up that question the sound properties of Prototype II will be extensively tested before the conversion.

PLAYABILITY

- String changes are almost the same as on a four string cello; only E- and A-string are a bit too close when playing in high positions on the A-string. (*Could be resolved by a steeper curving of bridge and fingerboard.*)
- After overcoming initial difficulties of finding the right notes on the 'new' string, playing the 6th Bach suite, the Arpeggione sonata and other pieces with difficult high passages could become a pleasure.

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[20] *A wolf is a disturbance of the vibration of a string on a certain pitch, caused by acoustical interferences between the vibrations of strings and the instrument's body. On a four-string cello it is usually most strongly present within the D-string's forth position, affecting pitches from E to G.*

MEETING WITH UEDA [2] *(April 23rd 2013)*

In order to deal with the above mentioned problems the following measures were taken:

- The sound post was slightly moved.
- The bridge was made slightly thinner.
- The bridge was slightly carved in order to lower the E-string and facilitate string changes from the neighboring A-string. The fingerboard was not changed for now, as this would have required a rather lengthy process.
- A wolf-killer (7 grams) was equipped.

To try to improve sound quality further, E- strings from different makers were ordered *(Jargar, Helicore)*.

The presently equipped tailpiece with its rather big and heavy adjusters also might be a possible source of sound loss.

Equipping smaller adjusters is quite expensive and still could account for some acoustic loss. Therefore it was agreed to try equipping fine-tuning pegs, which could eliminate the need for tailpiece adjusters.

Picture 12: The tailpiece, fine-adjusters and the wolf-killer, mounted on the G-string [*2nd string from the left*].

TEST RESULTS [2] *(Featuring the present tailpiece and a wolf-killer.)*

- String changes on upper strings present no problems anymore.
- Sound quality of E- and A-string became more similar; however, the slightly nasal character of the E-string is still present.
- Wolf is reduced but still present.

- **MEETING WITH UEDA** [3] *(May 13th, 2013)*

The ordered fine-tuning pegs *(Made by German manufacturer Wittner.)* were installed. They contain a sophisticated gear mechanism that allows an easy and precise tuning of each string without having to use adjusters on the tailpiece

The fine-adjusters were removed from the tailpiece. A little bridge was added on the top of the tailpiece in order to avoid direct contact of the strings to the tailpiece body. The size of the eyelets for taking the lower ends of the strings were measured differently for each string; making the high E-string the shortest and the low C-string the longest. This was done

in an attempt to take tension from the high strings and achieve a less nasal sound of the E-string.

Because of the removal of the tailpiece adjusters the distance of the string-length between bridge and tailpiece *(and thus also the overall length of the strings)* increased considerably, it was considered to change the position of the tailpiece by lengthening the cord it is attached by to the endpin socket. This will be done after the next testing period.

TEST RESULTS [3] *(Featuring fine-tuning pegs and a lighter tailpiece.)*

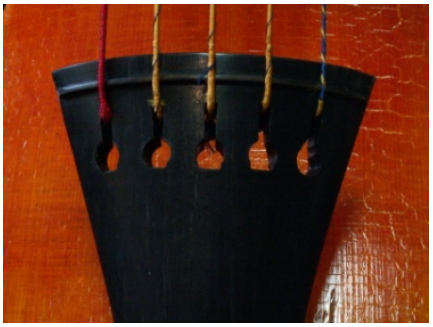
- The Wittner fine-tuning pegs are working perfectly and seem to make the use of adjusters on the tailpiece superfluous. *(Final judgment will require some more time of observation.*[21]*)*

  The lever mechanism inside the pegs provides a gear transmission of 8.5:1. This makes precise fine-tuning very easy. The number of necessary rotations of a peg to put a new string increases compared to traditional pegs, but not to an unreasonable extent.

  Since the strings will be stretched at a quite slow pace to their final pitch the danger of breaking them becomes much smaller. This is especially important in case of the very thin E-string.
- The new tailpiece presents a significant optical and practical but only a slight acoustic improvement. The overall sound quality has changed positively but the E-string's sound quality hasn't changed very much.

The installation of the fine-tuning pegs has allowed for some important insights of optimizing the outfit of any cello, not only the Prototype I. If they continue to function as at the present time they could be well considered as a permanent replacement for tailpiece adjusters. Certainly they have recommended themselves for the next Prototype and the project's final instrument because of the diminished risk of breaking the E-string when tuning. Acoustic advantage may be small but installment is financially justifiable while practicality is high.

Picture 13: The tailpiece in its present shape. Its head was designed to accommodate the adjusters and is therefore a little too wide. This will be considered to be corrected after having tested Prototype II which will be equipped with fine-tuning pegs from the start and a narrower tailpiece.



21 Two months after installation: Pitch sinks slightly after a couple of days. Whether this is due to the weather or the pegs moving is not clear yet.
Five months after installation: The sinking of the pitch has nothing to do with the pegs. They work perfectly and make the use of adjusters superfluous.

MEETING WITH UEDA [4] *(May 18th, 2013)*

The length of strings between tailpiece and bridge was shortened by 10mm. (*This lowers the tension of the strings and is supposed to soften the sound of the higher strings slightly.*) Additionally, a heavier wolf-killer (9 grams) was attached to the G string..

TEST RESULTS [4] *(Featuring fine-tuning pegs, lighter tailpiece, reduced string distance between tailpiece and bridge, heavier wolf-killer.)*

The nasal quality of the E-string changed a little to the better and the difference of sound quality between A- and E-string is now considerably less evident. Still, the instrument seems to have less resonance than a comparable four-string cello.

Since the sound properties were a little bit disappointing the team consulted about possible reasons and ways to obtain a better level of sound quality. Both Amati's and Stradivari's five-string cellos were smaller than their four-string models, so the team decided to build a second prototype in a size similar to the old masters' instruments. As a result the team ordered another low-priced four-string cello, this time in a size (*7/8 as compared to the usual 4/4*) as close as possible to the smaller Amati and Stradivari five-string cellos.

- **MEETING WITH UEDA [5]** (*May 23rd, 2013)*

The 7/8 cello, designed to become Prototype II, has arrived. It is a new, Chinese-made four string instrument *(Maker:A. Eastman.)* with a body length of 710 mm (4/4: 750) and string length from nut to bridge of 670 mm (4/4: 690mm).

TEST RESULTS [5] *(Featuring the new four-string cello without any changes)*

The cello was tested for several days and proved to have a quite balanced sound-quality through all strings and positions.

The sound properties of the new cello and the Prototype I then were digitally recorded and stored.

- **MEETING WITH UEDA [6]** *(May 27th, 2013)*

On May 27th the instrument was returned to Ekoda Strings and Ueda started to convert it into a five string cello.

TEST RESULTS [6]. *(Featuring Prototype I with a different E-string)*

On May 29th the Prototype I Larsen E-string was replaced by an E-string made by Helicore, a company which produces cello E-strings at a slightly lower price than others.

There is no noticeable difference to the Larsen string – neither in material nor in sound. The nasal property is still present.

This is as far as experimenting with Prototype I will go.

The next stage will consist in testing and recording of the five-string turned Eastman Prototype II which is currently worked-on by Ueda.

- **MEETING WITH UEDA** [7] *(July 6th, 2013)*

Prototype II has been finished and taken to be tested, recorded and photographed.[22]

PROTOTYPE II

CONSTRUCTION

The construction of Prototype II was basically the same as the construction of Prototype I. However, based on the knowledge gained from testing Prototype I, Prototype II was set up with a slightly narrower tailpiece without adjusters since fine-tuning pegs were installed right from the beginning. Also, similarly to Prototype I, the length of the strings was adjusted in order to favor the E- and A-string. Another difference is the shape and size of the bridge: Prototype II is equipped with a French-style bridge, while Prototype I features a Belgian-style bridge.[23]

Picture 14: Prototype II.

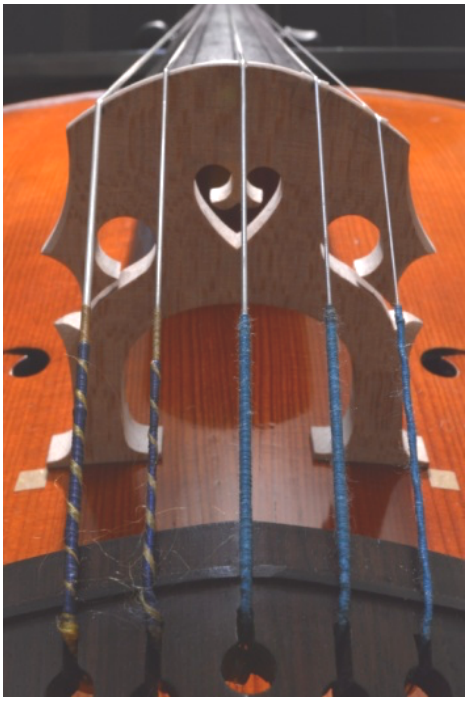
22 A digital SLR camera was purchased for easier and more precise documentation. (Until now Doll's and Ueda's private point-and-shoot cameras were used). The camera is equipped with a 18-55mm f/3.5-5.6 lens and greatly facilitates the taking and uploading of sharp pictures and close-ups of static objects in confined spaces

23 Belgian bridges have long legs, a slight body and produce a strong and bright sound color. French bridges have shorter legs, a bigger body and produce a gentler and warmer sound color.

Bridge measurements			**Tailpiece measurements**
	Body width:	**Distance between feet:**	**Width of head:**
Prototype I:	*74mm*	*92mm*	*85mm*
Prototype II:	*84mm*	*92mm*	*70mm*
Four-string:	*70mm*	*92mm*	*60mm*

The instrument is still equipped with the strings it came with *(C-string and G-string: Helicore; D-string and A-string: Jargar.)* in order to be able to compare its sound to the sound in its original four-stringed form. As the E-string this time a *Jargar* string was used.

Picture 15: The French bridge of Prototype II. The yellow seals at the bridge's feet are Ueda's reminders of the bridge's optimal positioning. The adjusting of tailpieces and the changing of strings requires frequent removing and re-equipping of the bridge and t is very important that the bridge is replaced at the exact same place. For that reason easily removable seals that leave no tracks on the lacquer are used.



TEST RESULTS [7]. *(Featuring Prototype II (7/8 size), equipped with French bridge, fine-tuning pegs, narrow tail piece and E-,A,-D- strings made by Jargar and G-,.D-strings made by Helicore .)*

FIRST IMPRESSIONS

- E-string's volume is quite strong. However, quality still is gamba-like.
- D- and G-string have a muted, muffled sound-quality in positions above third.
- Wolf-notes around the E/F area – more or less present on all strings.
- Overall the instrument seems to have lost some of its overtones and volume, especially in the lower registers.

MEETING WITH UEDA [8] *(July 17th, 2013)*

Today Prototype I and II were compared side by side for the first time.

TEST RESULTS [8]. *(Featuring Prototypes I and II in their presumably best set-up.)*

SIMILARITIES

- Both instruments' E-strings have a sound quality that is untypically for a cello; they sound rather like a viola da gamba or a treble.
- Both instruments' A-strings sound slightly muffled compared to a four string cello.
- Both instruments' D- and G-strings lack overtones; especially in the higher positions.
- Generally the sound volume of both instruments is smaller than of a four-string cello..

DIFFERENCES

- Prototype II responds better and generally produces a stronger and clearer sound than Prototype I.
- The E-string of Prototype II has a slightly less nasal quality then the E-string of Prototype I.
- The wolf notes on Prototype II are less disturbing than the wolf notes on Prototype I.

FURTHER ACTIONS ON 8th MEETING

The length of strings between the tailpiece and bridge from Prototype I was lengthened from 110 to 115 mm. This action favors the high strings' quality and volume. There was a noticeable, positive change. Still, Prototype II has a better overall sound quality.

(The cost of changing a four string cello into a five string cello turned out to range between 1.000.000 ¥ and 2.000.000 ¥, depending on the quality of the used material.)

CONCLUSIONS

The smaller sized Prototype II turned out to have the better sound properties of the two prototypes. However, there is a noticeable loss of volume and sound quality compared to an original four string Eastman cello. Those facts result in the following recognitions:

- Five-string cellos seem to have a lesser sound volume than four string cellos. (The particular explanation for that fact still has to be explored.)
- Smaller five string cellos seem to have better sound properties than regular-sized five string cellos
- However, Prototype II still lost some of its sound properties after being converted to a five string instrument. Therefore, at this point of the research, conversions of four string cellos cannot be recommended until the construction of an original, high-level five string cello is completed.

These realizations already present a prominent result of progress of this project: Amati's and Stradivari's decision to build their five string cellos in a smaller scale than their four-stringed instruments had to be based on the same experiences we made while experimenting with our two prototypes.

III. CONSTRUCTION OF THE FINAL INSTRUMENT

The next step will be the construction of the third and final version of the project's five-string cellos. The prototype both are conversions of instruments of a very low price range. They served their purpose of allowing numerous experimentations which led to important conclusions but cannot compare to an instrument handcrafted by a master.

The reason of the low price of both prototypes lies not only in the use of cheap material. The cost of the material needed for a high level instrument amounts to about 20 to 30% of the end price. The remaining percentage is the cost of labor the master has to spend in order to craft a unique, expertly made, beautiful new instrument. A cheap instrument is usually built by a group of people, sometimes even in a big factory. Different parts of the instrument are crafted from different people even when the instrument's label will probably show only one name, the owner of the shop or the factory. Machines are used as much as possible in order to save time and money. But machines cannot recognize the special properties and differences of each piece of wood. They also cannot take in account the subtle asymmetries of the instruments of the masters. *(See picture 21 and 22.)* A master's instruments will be lovingly cut, carved and varnished by two hands only, following the plans and experience of over 400 years of craftsmanship. It then will be tested, changed, tested again and changed again for many times.

It will take Ueda quite some time to produce a beautiful cello for our project and we will document each single step of it.

THE MATERIAL

For the building of a fine string instrument the use of superior material is of essence. One important factor is the age of the wood to be used: The older-and therefore dryer and lighter-the wood is, the better is its resonance. Old wood also does not change its structure anymore; a fact that makes sure the instrument itself will not change its sound properties over the years.

For the belly of the instrument Ueda purchased two pieces of spruce[24], cut in 1985, for the price of 15.750 ¥. This seems to be a steep price for two pieces of wood but there are not many market places for old wood - most people tend to purchase new and cheap wood for constructing wooden devices. Unprocessed old wood of high quality is very rare: one of the few places where one can find that kind of material is the shop of an established violin maker. Master violin makers use wood that was cut in the first half of winter, when the amount of sap within the tree has reached a minimal level. They then let the wood dry for as many years as possible before they use it for building their instruments. Since they intend to use that precious material for their own instruments they generally do not want to sell it unless for a substantial price.

Fortunately Ueda could obtain the necessary material from the stock of his former master and teacher for a very reasonable amount of money.

Picture 16: The two boards designed to become the belly of the final five string cello. Their cut is already hinting at the final shape.

For the bottom Ueda chose two maple pieces, also cut in 1985, for the price of 63.000 ¥. Maple wood is rather expensive because of its exquisite graining. A beautiful, symmetrical graining of the bottom of an instrument is a substantial factor for the esthetical property of a string instrument. It is also something like the calling card of a violin maker. The bottom pieces are also cut into wedges but are thinner than the belly pieces.

24 Spruce wood is light, strong and has excellent sound properties.

Picture 17: The graining of one of the bottom boards.

The ribs *(the side walls of the body)*, also maple, were cut in 1982 and were included in the price of the top and bottom set.

Picture 18: The boards that become the ribs of the final five-stringed cello. They are about 120cm tall. The board in the middle was turned by 90° in order to demonstrate how thin it is..

For the scroll and neck Ueda purchased a massive block of maple wood with the same age as the belly and bottom, priced at 15.750 ¥.

Picture 19: The block that will be used for scroll and neck. Ueda already roughly sketched the shape of the scroll onto it.

Instead of manufacturing a new fingerboard Ueda again will convert a bass fingerboard and adjust it to a size and shape that fits a five string cello. Manufacturing most parts of the final five-string cello will definitively cause a noticeable improvement of quality with the new instrument. However, manufacturing a completely new fingerboard is not a necessary part of our project: a high-grade bass fingerboard and a high-grade cello fingerboard are made from the very same material: ebony wood. Using a converted bass high-grade fingerboard will have absolutely no negative influence on the sound properties of the instrument but, on the other hand, it will save time and money.

The tailpiece too will be hand-made and, again, not be equipped with fine-adjusters. Instead, the fine-tuning pegs that have proved to be very practical with Prototype I and II will be used.

MEETING WITH UEDA [9] *(August 30th 2013)*

CHOSING THE MODEL

The project's research showed that there were almost countless types of cellos over the centuries.

Following the conclusions drawn after testing the two prototypes the team decided to build the project's final instrument as a Stradivari-type cello with a slightly smaller size than the usual 4/4 size.

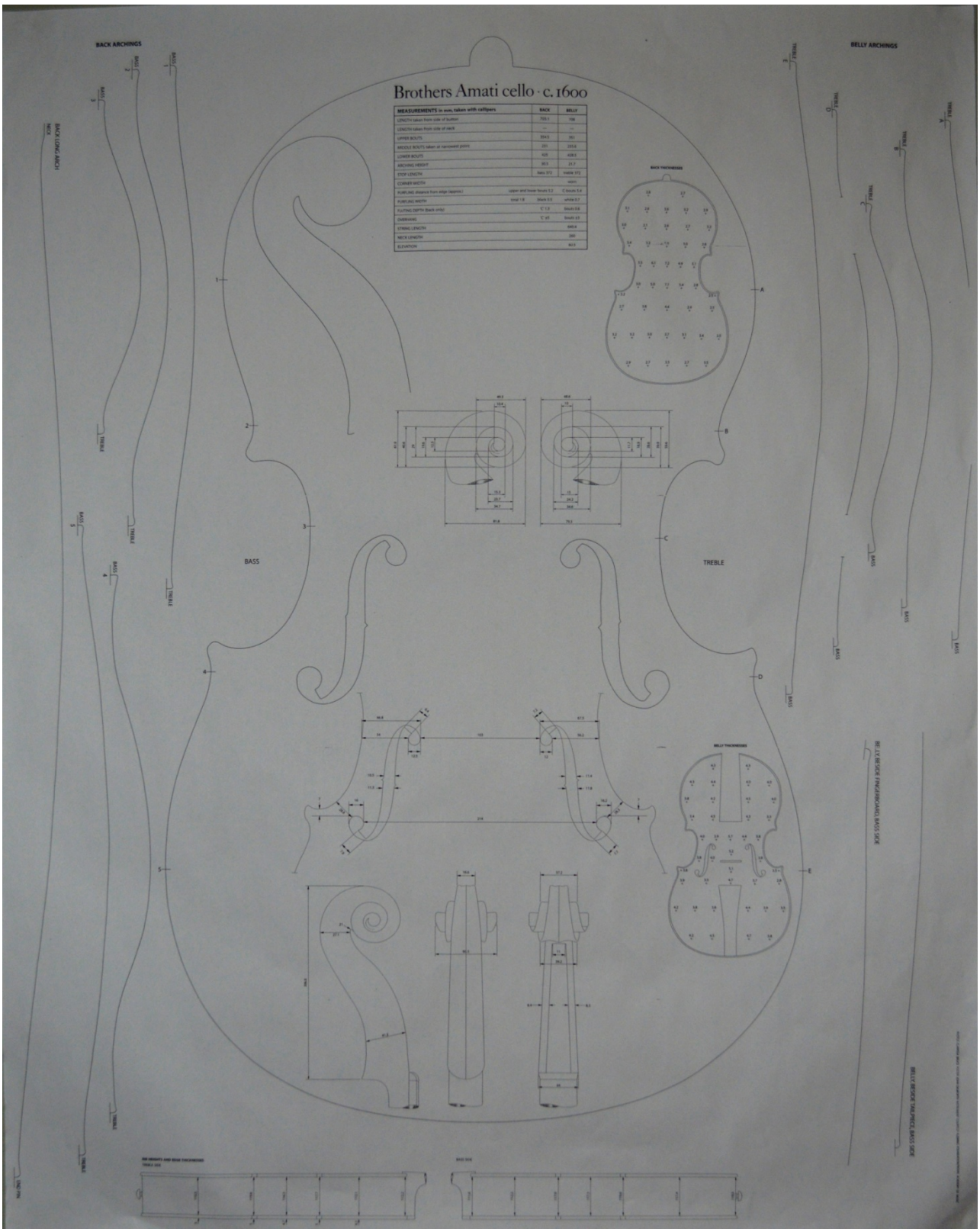
In the meantime Ueda had managed to temporarily lay his hands on photos and a poster[25] (*showing all important measurements in the original size*) of a five-stringed cello[26], built by the Amati brothers Antonio and Girolamo around 1600.

Picture 20: The five string cello from the Amati brothers Antonio (ca. 1537-1607) and Girolamo (ca. 1551–1630); Body length: 707 cm - slightly smaller than a 7/8 modern cello; distance from nut to bridge: 640 mm – 30mm less than a 7/8 cello's.

25 Both were photo-copied and returned to their owner.

26 Photo and poster were a supplement to an edition of the magazine 'The Strad'.

Picture 21: The complete measurements of the Amati brothers' five string cello[27].



27 The photos of the Amatis' measurements were taken from the poster created by John Dilworth that came with an edition of the magazine 'The Strad'.

COMPARISON OF THE PROJECT'S CELLOS' OUTER MEASUREMENTS:

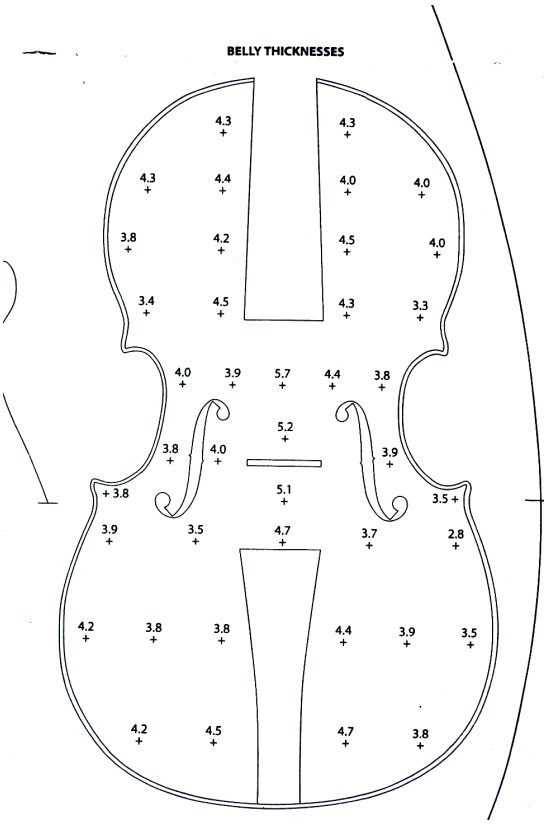
	Prototype I	**Prototype II**	**Amati**
LENGTH OF BODY:	750mm	710mm	705mm
LENGTH OF STRINGS[28]:	690mm	670mm	640mm
WIDTH OF UPPER BODY:	340mm	325mm	354mm
WIDTH OF MIDDLE BODY:	250mm	225mm	235mm
WIDTH OF LOWER BODY:	440mm	415mm	425mm

The Amati model has the smallest body length of the three instruments. It might make its use a little awkward, but the real concern is the considerable difference of length of strings; today's cellists' left hands are used to the 4/4 sized cello's length of 690mm. Switching to an instrument with a difference length of strings up to 5cm will certainly cause adjustment problems.

This problem has to be dealt with when building the project's final cello.

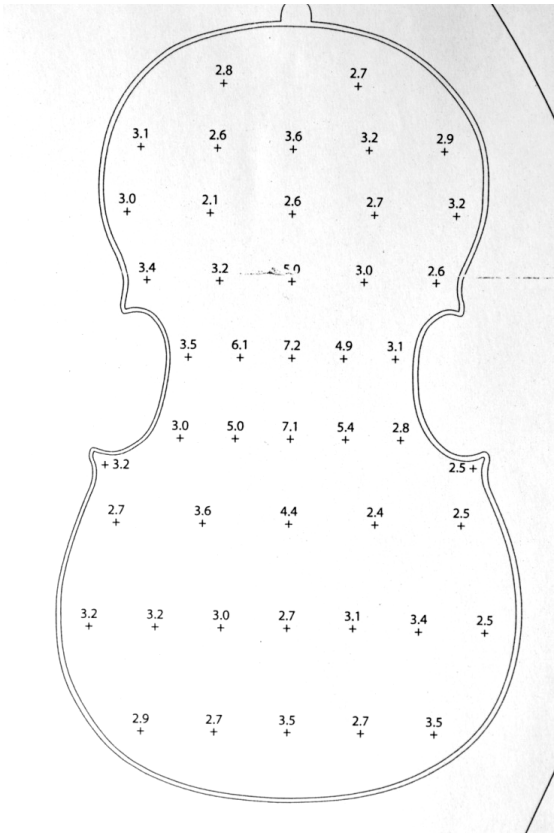
THICKNESS OF BELLY AND BOTTOM

Picture 22: The Amatis' cello's belly. The numbers represent the measurements in millimeters. The + signs indicate the places of measurement..



28 Measured from bridge to nut.

Picture 23: Measurements of the Amatis' cello's bottom.



The pictures illustrate the non-symmetrical structure of the belly and bottom of the instrument. That fact is a very substantial point, supporting the decision to produce a hand-made instrument. Following those measurements requires very cautious, slow work, involving precise and frequent measuring: a mistake like taking off one millimeter too much cannot be corrected. Fast and cheap production cannot deliver that kind of precision.

BELLY:

The Amatis' and Stradivari's measurements are the result of careful calculations and countless trials. A violin maker wants the belly and back as thin as possible without risking the static stability of the instrument. A thin belly and a thin bottom allow the body to vibrate more easily, which will result in a better responsiveness of the strings and a bigger sound.

On the other hand, since the tension of the strings cause quite a lot of pressure, mainly onto the belly, a too thinly constructed instrument could end up with a sinking or even cracking belly when the strings are being mounted and tuned to their respective pitch. A thicker body will provide stability but will have worse sound properties.

The Amatis' solution for this problem was making their cello's belly thicker than the bottom and using an asymmetrical pattern of thickness for both. It was the same decision their father, Andrea Amati, and later Antonio Stradivari took for their four string cellos. The lower strings are much thicker than the higher strings and thus produce more pressure onto the belly. That is the reason why the masters decided to make the bass sides in general thicker than the treble sides. That way belly and bottom are strong where a lot of pressure is present and thin where less strength is needed.

BOTTOM:

The bottom is generally about 40% thinner than the belly with one exception: the place around the sound post and below the bridge. The sound post transfers considerable pressure from the bridge to the bottom. For that reason the Amati design demands in the area around the sound post's position 7.1 mm and in the area under the bridge 7.2mm. This is more than the thickest part of the belly (5.7mm).

Otherwise the asymmetric pattern is very much like the belly's design: the bass side is thicker than the treble side.

Surprisingly the general thickness of this five string cello's belly and bottom is only very slightly different from a four string Stradivari-type cello's measures; one would have expected for example a substantially thicker belly in compensation for the additional pressure of the fifth string. Obviously, besides the body length, the general measurements of a five string cello do not have to change to a major degree.

OUTER MEASURES OF THE BODY

CONTOURS

Basically the contour of the Amati five-stringed cello is very close to the final shape Stradivari decided about in the early 18th century for the four-string model. One difference was already pointed out: the lesser length of the Amatis' cello's body. Presumably the reason for that were the static and acoustic changes resulting from adding a string – the four string cellos manufactured by the Amati family generally have the usual length of around 750mm.

In the year 1600 Antonio was 63 and Girolamo was 49 years old. They did build cellos before 1600 that were bigger (lengths between 730 and 750mm) than the five string cello (705mm). It also is a fact that their father Andrea Amati (1505-1577) was the first master who established the measurements that became the fundament of the Stradivari model: Andrea's cellos already had measurements around 750mm (length), 35mm (shoulders) and 44mm (hips). *(Stradivari's model featured only relatively minor changes of the Amati model. Stradivari's importance lies in the fact that his changes were the last ones.)* Therefore, it can safely be assumed that the brothers' five string cello was a try to make step ahead from the Andrea Amati and the later Stradivari model: it would make no sense to return to the gamba design at a time, when the new four string cello already had proved its superiority.

There is only one possible explanation for the brothers' experiment: They wanted to build a five string cello that stayed as close as possible to the new cello's shape but offered new opportunities.

Those new opportunities and the true reason why they wanted to construct a five string instrument at that time can only be speculated about; they probably wanted to expand the tonal range of the cello, either on a general purpose or for the easier execution of some particular pieces that could be performed easier with a fifth string.

(*The Amati five-string cello is presently in the museum of the Royal Academic of Music of London. It is equipped as a baroque cello and can therefore not serve as material for comparison to a cello with modern equipment.*[29])

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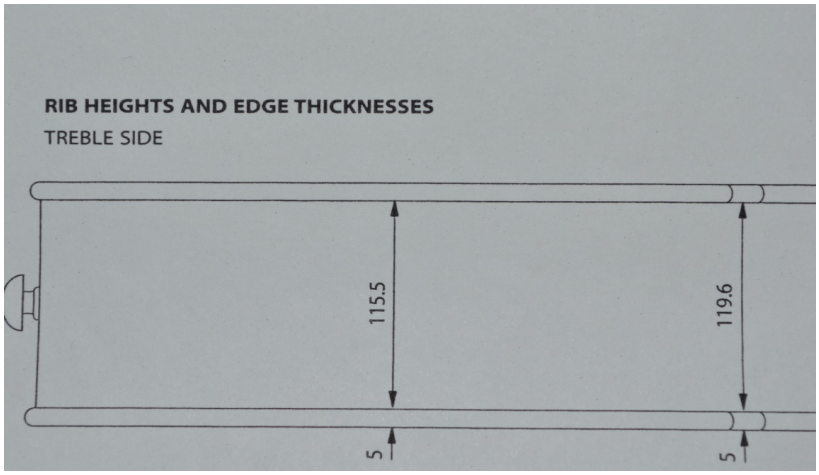
29 Modern equipment mainly means stronger strings. That seems to be a minor factor but with the development of stronger strings over the centuries the violin makers had to adapt their instruments' bodies to the growing pressure on the body. That is the reason why a modern cello's structure is quite different from a baroque cello's. A baroque cello could not take the pressure of steel strings.

BODY HEIGHT

The term body height here refers not to the length from the top of the scroll to the end of the tail piece but to the height of the ribs of the instrument.

***Picture 24**:* Lower treble side rib of the Amati five string cello.



The Amati has rib measurements of between 112 and 130mm, with128mm at the shoulders and 130 mm at the hip, including the edges from belly and bottom. (*If one sees a cello one assumes that its shape is perfectly symmetrical and regular. The measurements of the lower treble side rib (picture 24) and the measurements of belly and bottom (pictures 21 and 22) however illustrate that the Amatis obviously decided about several deviations from the principle of symmetry. That is true not only for this particular instrument: other Amati and also the Stradivari four string cellos show asymmetric measurements of body thickness and height. As mentioned before, this is the way how the masters dealt with the irregular distribution of pressure on belly and bottom*.)

The rib height of the Amati five string cello is somewhat surprising: the Stradivari models have an average height of 120mm (shoulders) and 130mm (hips) and the 7/8 Prototype II has respective measurements of 122 and 126mm. Considering the reduced length (705mm) of the Amati (Stradivari's average length is 750mm) one should expect a proportionally reduced body height. But the Amati has the same rib height at the hip as a Stradivari full-size cello and its shoulder is even a little higher than a Stradivari's average shoulder. The comparison of Prototype I and II showed that a slight sacrificing of body length results in better sound properties. However, reducing the height proportionally would not positively affect sound properties[30]: the ribs do not play a significant role in the acoustic system of a string instrument; they do not really transport vibrations from the belly to the bottom: that task is the sound post's main job. (*Touching the ribs while playing will not change the sound, while touching belly or bottom will considerably disturb vibrations and muffle the sound.*) The Amatis obviously wanted to keep the body volume as big as possible.

A Stradivari-type cello has basically the same proportions as a violin but is approximately twice the size. The only major difference is the height: the cello's height is four times the height of a violin. Like to the Amati brothers with their five string cello it seemed important to Stradivari to get the biggest body volume possible, probably in an attempt to make up for certain acoustical losses, caused by enlarging the violin measurements. It is a surprising fact that the sound volume of string instruments becomes smaller with growing size. For example the viola (*average body length: 41cm*) is not much bigger than a

30 The 7/8 Prototype II does have smaller height than a 4/4 instrument. The reason for this is the intention of creating a usable four string cello for small persons while accepting possible downside s of having a smaller volume.

violin (*average body length 36cm*) but has a distinctly smaller sound. The by far biggest string instrument, the double bass, has the smallest sound of the orchestra string instruments.

The lower registers and the longer strings with their lower speed of vibration are one reason for the loss of volume with bigger instruments. Another important factor is the size of the body: bigger bodies require more material and have to feature thicker bellies, bottoms and ribs which results in some loss of responsiveness to the vibration of the strings.

After having studied the Amatis' instrument's measurements it was concluded to follow the inner construction design (thickness of belly and bottom) of the Amatis' cello as close as possible.

However, the string length of only 640mm cannot be tolerable: the project's final cello should an instrument that can be used by any cellist without major special adaption. Preserving the Amatis' outer body measures and only change the strings' length to an acceptable 660 to 670mm by prolonging the instrument's neck would result in a general esthetic misbalance of the instrument and also might cause negative changes concerning sound and usability.

Thus it was decided, while following the Amatis' inner design, to use the outer measurements of a small, master-made four string cello.

MEETING WITH UEDA [10] *(October 11th, 2013)*

After an extensive search Ueda found a cello that might be ideal as the model for the project's final five string cello's contours. It is a beautiful four string cello, the so-called 'Ngeringa' cello, built in 1743 by Giovanni Battista Guadagnini in Parma. Generally all of the Guadagnini cellos are rather small, but this one has the perfect measurements for the project's purposes.

Picture 25: The Guadagnini 'Ngeringa' cello**.**

OUTER MEASUREMENTS OF THE PROJECT'S FINAL CELLO:

	Final design: Amati / Guadagnini / Ueda	*Prototype I*	*Prototype II*	*Amati*
LENGTH OF BODY:	**715mm**	*750mm*	*710mm*	*705mm*
LENGTH OF STRINGS[31]:	**665mm**	*690mm*	*670mm*	*640mm*
WIDTH OF UPPER BODY:	**330mm**	*340mm*	*325mm*	*354mm*
WIDTH OF MIDDLE BODY:	**240mm**	*250mm*	*225mm*	*235mm*
WIDTH OF LOWER BODY:	**425mm**	*440mm*	*415mm*	*425mm*

(Those are the outer measurements of the instrument. The inner measurements (thickness of belly and bottom; heights of bouts) will still follow the Amati design.)

SPECIAL EVENT I

FIRST INTRODUCTION OF THE PROTOTYPES TO THE PUBLIC

When planning the 4th recital (2014, May 13th) of their cello ensemble ANTIQUITAS Doll and Yamazaki decided to use the two prototypes for a small part of the concert in order to get some early publicity for the project.

Doll transcribed several pieces, originally composed for treble- (fiddle-) and viola da gamba ensembles, using the prototypes like trebles with their high upper string. The unique sound quality of this ensemble, which came actually quite close to the sound of an ensemble using Renaissance instruments, caused quite some amount of interest and appreciation.

(Note: Since this recital was not a part of the funded research project it was financed by ANTIQUITAS.)

The ANTIQUITAS ensemble, from left: Doll, Yamazaki, A.Sekine., K.Sekine.. (Picture: AYUMI IGUCHI.)

31 Measured from bridge to nut.

CONSTRUCTION I / Form, Blocks

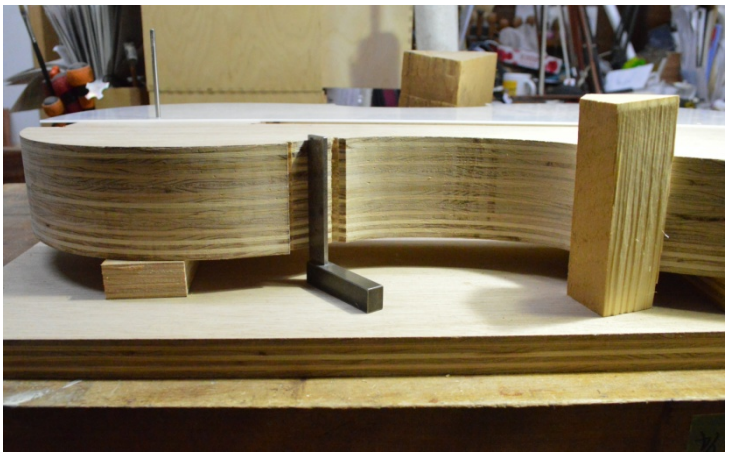
(The following describes the construction process from January 2014 to March 2014)

Ueada's first step was the production of an exact copy of the Guadagnini's shape ('Schablone[32]), using a thin plastic sheet

Picture 26: The copy of the Guadagnini's shape **.**

This sheet he used to construct the so-called 'form[33]' – a device that serves as a template for the future instrument.

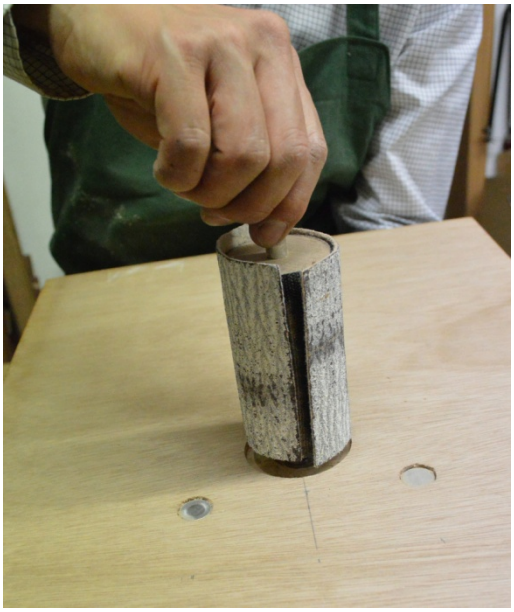
Picture 27 and 28: The form; the blocks and a measuring tool.



For the production of the form first a big band saw was used. For the final fine-touching Ueda used a tool called a sander, which can be attached to an electric drill machine.

32 Schablone (German) = template

33 Form (German) = form



Picture 29: The sander**.**

The blocks seen in the pictures 27 and 28 will be used for the corners of the C-bouts. The measuring tool is used to assure the bout's straightness.

At the same time Ueda started to work on the back parts of the instruments, using planes of decreasing size. The goal is to make the two parts of the back fitting perfectly together.

Picture 30 and 31: Working on a part of the back.

CONSTRUCTION II / Bouts

*(**Note:*** Until indicated otherwise the following constructing-process will not differ from the constructing-process of a four string cello. Please skip this part if you already know about the basic construction of a cello. Because we did not, and assumed that most cellists don't either, we included those steps in this report.)

In the beginning of May 2014 Ueda started to work on the bouts of the new instrument. In order to assure the bouts fit in a perfect angle to the form he placed the form on a glass plate.

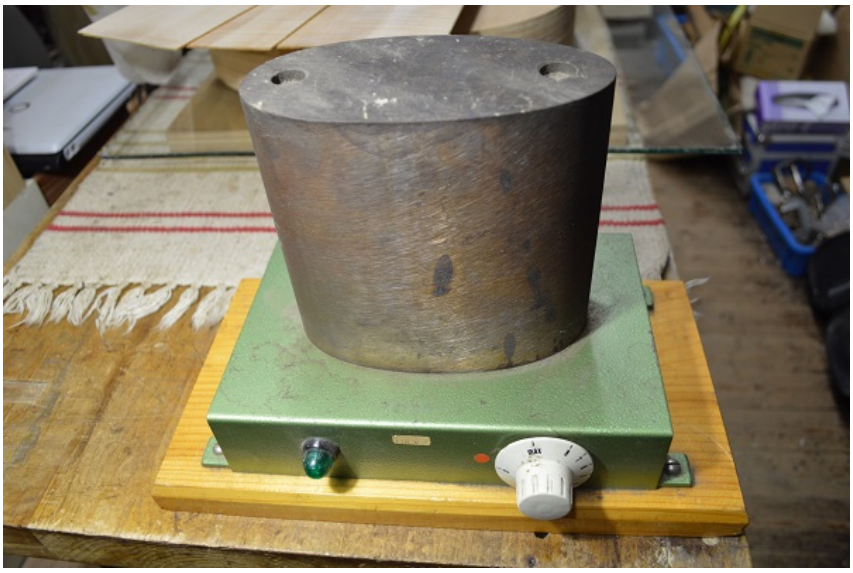
Picture 32: The form on a glass plate. The blocks are now glued-on but will be removed later together with the completed bouts.

He then cut the wood intended to become the bouts into 6 separate stripes.

Picture 33: A selection of the bout stripes.

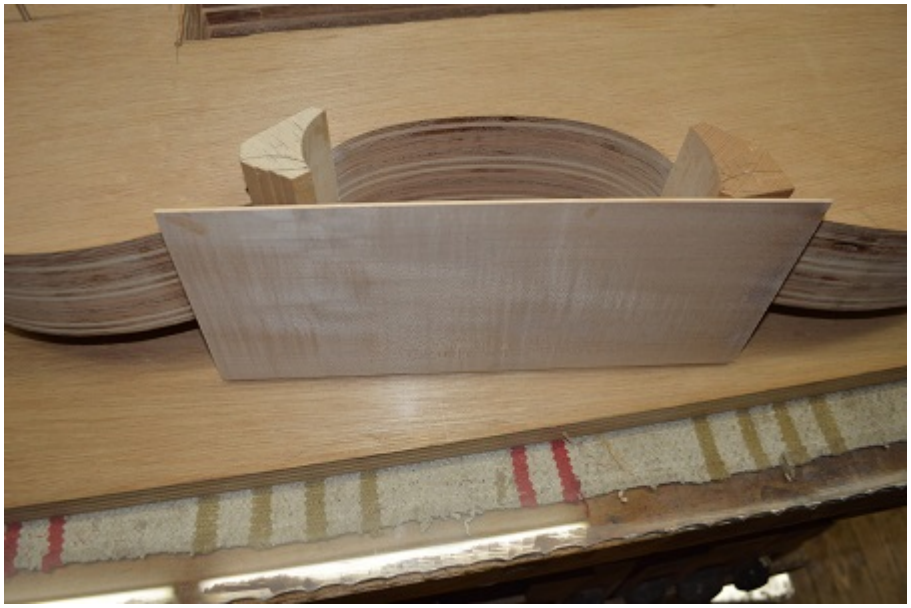
For the necessary bending of the bout stripes Ueda prepared to use a tool called bending iron. It is an oval block of iron that can be electrically heated to temperatures well over 100 degrees Celsius.

Picture 34: The bending iron.



The first bout stripe Ueda started with was one of the C-bouts.

Picture 35: A C-bout stripe before the bending process.



While heating up the iron he put the C-bout stripe for some minutes into a bowl of water. He then covered the moist stripe with a piece of paper which is supposed to increase the amount of steam that is necessary to bend the wood. Using a flexible metal plate he then started bending the bout on the hot iron, a process that requires quite a lot of physical force.

Picture 36 and 37: Bending a C-bout stripe.

The bending process needs to be repeated frequently until the piece fits perfectly to the form. Picture 38 shows the first result and pictures 39 and 40 show the preparations for the first adjustments by marking irregular parts and whetting selected areas of the bout with water before bending it again.

Picture 38, 39 and 40

Picture 41: Fitting the C-bout into place.

After Ueda had fit in the second C-bout he carved the corner blocks to their final shape.

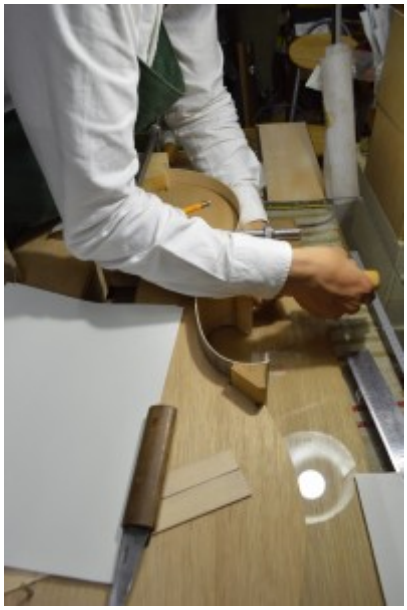
Picture 42: Second C-bout and shaped blocks. (At this moment the C-bouts are already glued-on. Later pictures will illustrate the gluing procedure in greater detail.)

The next pictures show the process of bending and positioning one of the shoulder bouts.

Picture 43: Measuring the length of the shoulder bout.

Picture 44: Bending of the shoulder bout.

Picture 45 and 46: First fittings of the shoulder bout.



Picture 47: **P**ositioning of the shoulder bout.

In the next procedure the upper bouts will be glued onto the neck- and the C-bout blocks. The glue master violin makers use is made from boiled animal hide, usually from cows' or horses' hides. Its cohesive power is much superior to the emulsions bonds' used for cheap instruments or cheap furniture. It usually comes in granulated form, but also in stick shapes.

Picture 48: The glue in its unheated form.

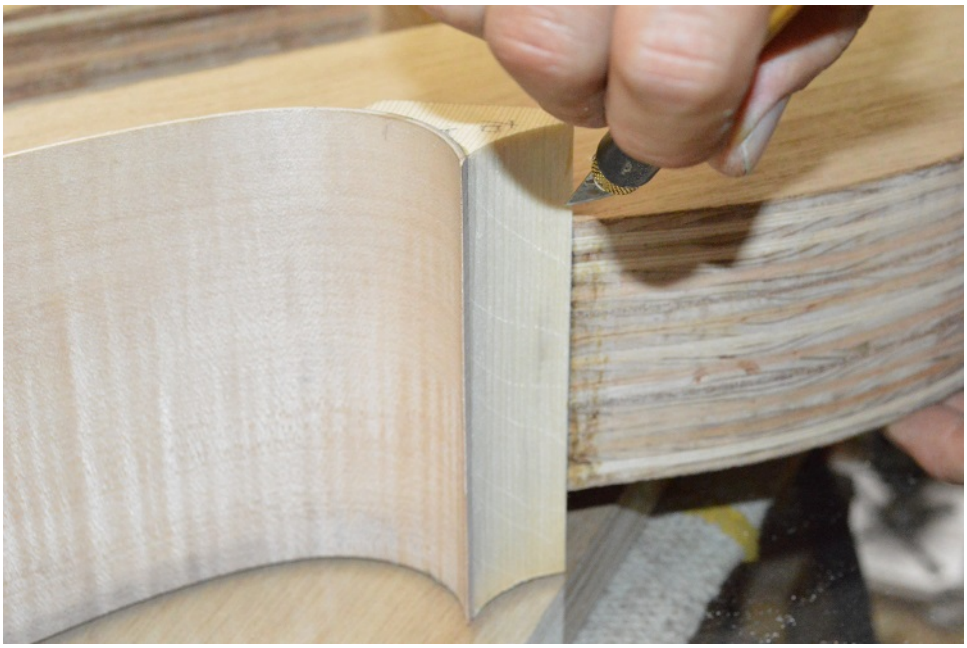
The glue then is slowly heated in water to 70-80 degrees Celsius which takes about 30 to 40 minutes. Bringing it to a boiling point would destroy its structure and make it useless. Master violin makers only heat up the amount they want to use in one session; if there is any leftover they prefer throwing it away over heating it up again at a later session.

Picture 49: The heated glue.

Picture 50: Testing the consistency of the glue.

The relevant blocks then are scratched in several places to allow for deeper penetration of the glue into the wood. In order to avoid the bouts sticking to the form near the blocks because of possible spill-over of glue, soap is being applied near the blocks. The block then is pre-heated with a dryer to avoid a sudden cooling-down of the glue when coming in contact with the wood which would have a negative influence on its cohesive power.

Picture 51: Scratching of a block.



P*icture 52:* Soaping.

Picture 53: Pre-warming.

Picture 54: Applying glue to the neck bouts.

To avoid the pre-heated blocks to cool down the glue is applied very quickly and the bouts are fixed into place immediately.

Picture 55: Fixing bouts to the neck end.

Picture 56: Putting glue on at the C-bout.

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Picture 57: Both upper bouts are fixed into place.

Picture 58 and 59: Bouts are complete.

After completing the bout frame the linings were produced. Linings are used as a reinforcement of the bouts on the inner side of the frame.

Picture 60 and 61: Preparation of the lining

The six parts will be bent with the bending iron and then will be glued to the inner upper part of the bout frame. The inner lower part linings will be glued-in after the form has been removed. *(There are also different approaches, for example the J.Kantuscher system, which uses a collapsible form that can be removed after all the linings are glued-in. In this project the traditional solid form will be used.)*

Picture 62: Bending a C-bout lining.

Picture 63: Opening a C-bout block before inserting the lining.

Picture 64: Fitting-in of the lining of a C-bout.

Picture 65: Shoulder lining in position.

This basically finishes the construction of the bouts. The second lining will be added after the belly is glued on and the form is removed.

SPECIAL EVENT II

FIRST FACULTY DEVELOPMENT (FD) PRESENTATION OF THE PROJECT

On July 15, 2014 Doll and Yamazaki introduced the Musashino String Department to the five string cello project at a FD event, following a regular string conference. The purpose of the project and the proceedings of the application for the government funds were explained. Doll then presented the Prototype II and answered questions from the teachers who showed a high amount of interest in the project and its future.

FD lecture. (Pictures: K. SHIBA.)

There will be at least one more FD event after the production of the final instrument has been finished.

CONSTRUCTION III / Back; Top

*(**Note:** Until indicated otherwise the following construction-process will not differ from the construction-process of a four string cello. Please skip this part if you already know about the basic construction of a cello. Because we did not, and assumed that most cellists don't either, we included those steps in this report.)*

After finishing the bouts Ueda started with the construction of the backside of the instrument's body.

Picture 66: Back pieces glued together.

After the glue was hardened the back was being planed.

***Picture 67 and 68**:* Planing and checking evenness.

When the planing process was finished the contour of the bouts was sketched onto the back.

Picture 70: Transferring the contour of the bouts.

Then, using a washer, 3mm were added to the contour. The back will be cut close to this line, creating the provisional overlapping rim that is necessary to protect the bouts from damage and that ensures the beautiful shape of the instrument.

Picture 71: Drawing the contour of the edge.

The back piece then was cut with a special saw as close as possible to the outer pencil marking in order to minimize the final adjustment work. The blur in the next picture is due to a slow shutter speed intentionally chosen to show the rapid up-down motion of this type of saw. For cutting smaller parts of wood usually band saws (equipped with a long circular band blade, rotating in just one direction within the machine) are used, but those saws come generally in sizes that are not suited for work on long and big parts of wood.

Picture 72: Cutting the back.

The back has been cut-out quite closely to the penciled contour but there will still be some corrections necessary, especially at the C-bout parts and the neck.

Picture 74: The cut back side, outer side.

The top was then cut in a similar fashion.

Next, Ueda started to plane both parts' upper sides in order to start the work on the final arching.

Picture 75: Planing the top.

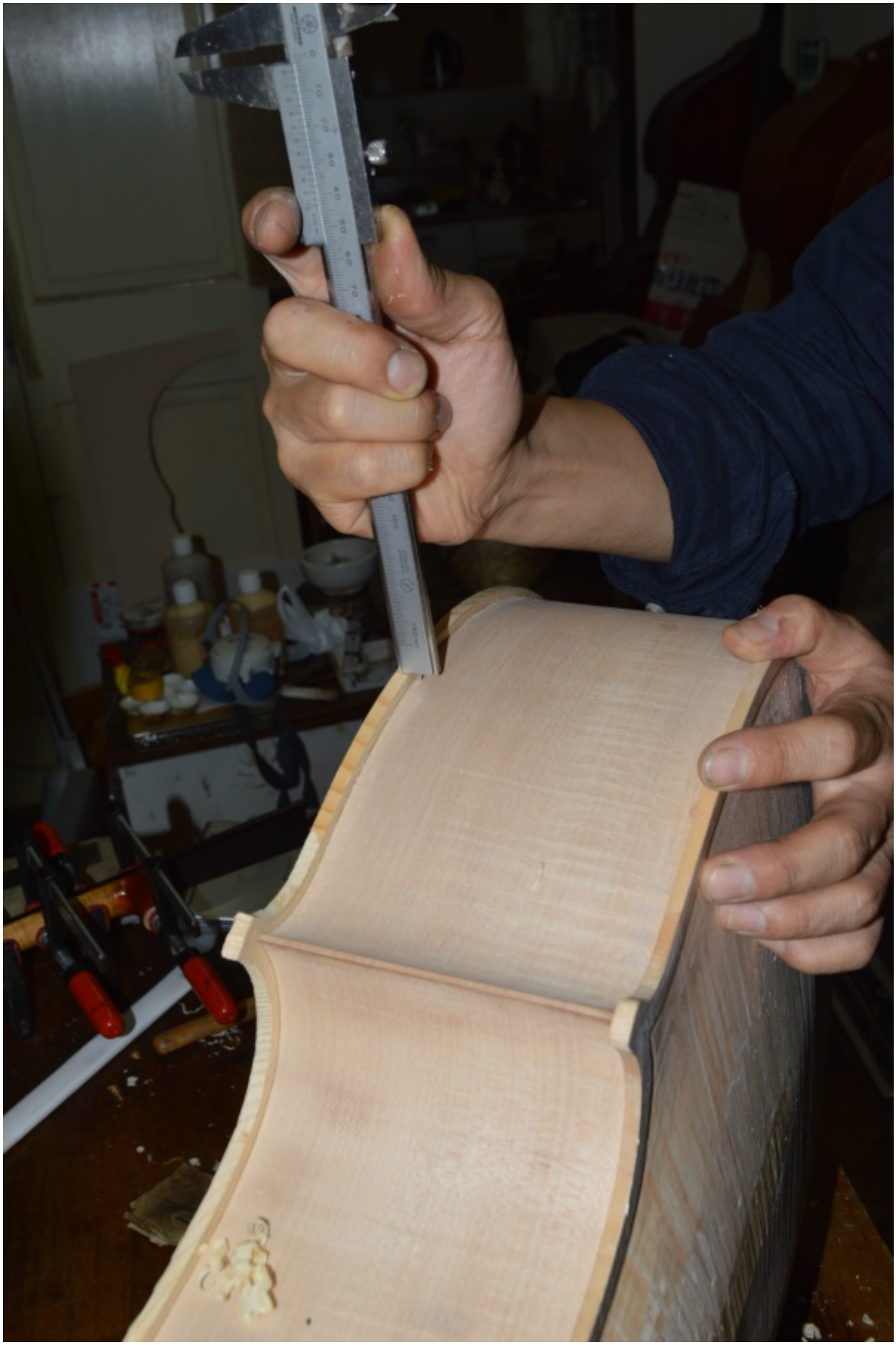
Picture 76: Some of the tools used in the planing-, arching process.

When the surfaces of back and top had approximately reached their final arching the body was temporarily glued together. (At this state the form is still inside of the body.)

Picture 76 and 77: The temporarily glued-together body.

This process serves the purpose of creating the final contour of the cello. The rim will be cut down to 3.5 mm, leaving some space for final corrections.

Picture 78, 79 and 80: The rim and the tools that are used for cutting it down. (Planing, filing, measuring.)



After the contour is perfectly taken down to 3.5 mm from the bouts the body will be taken apart again and the work on the inner arching of both bottom and top will begin.

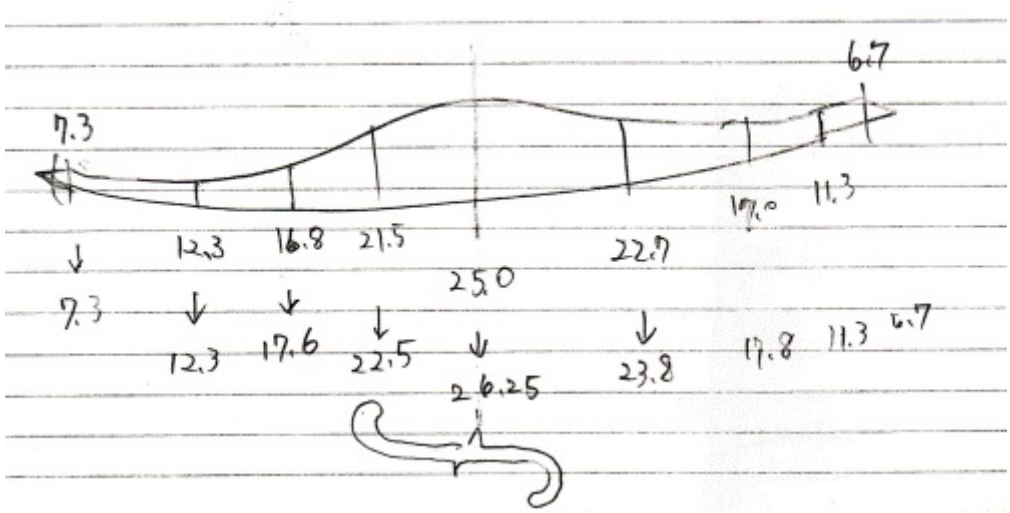
FURTHER EXPERIMENTS WITH PROTOTYPE II

At this stage of the construction there was still time to draw some conclusions for the construction of the final instrument. The main question was how much a stronger bass bar, possibly needed to accommodate for the additional pressure of the E-string, would change the sound qualities of the instrument.

Ueda increased the height of the new bass bar about 5%. The thickness remained the same (11mm).

Picture 81 shows the measurements of the bass bar. Numbers above are the old measurements; numbers below are the new measures. The F-hole was drawn to show the positioning.

Picture 81: Measurements of the bass bar. (Sketch: Ueda.)



The installing of the new bass bar at first resulted in a rather big loss of volume on the lower strings. After a few days most of the original quality returned but the experience brought up some doubt whether the merits of a stronger bass bar are big enough to justify a possible loss of sound.

Another change was a further lengthening of the E-string's distance between bridge and tailpiece. This resulted in quite a significant improvement of the string's sound quality.

CONSTRUCTION IV / Assembly of the body

(**Note:** *Until indicated otherwise the following construction-process will not differ from the construction-process of a four string cello. Please skip this part if you already know about the basic construction of a cello. Because we did not, and assumed that most cellists don't either, we included those steps in this report.)*

After the back was carved to its final shape it was glued-on permanently to the bouts.

***Picture 82*:** Carved back clamped-on for drying.

***Picture 83*:** Glued-on back..

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***Picture 84*:** Fitting the bass bar onto the finished top.

Picture 85 and 86: Removing the form.

Picture 87: *Form is removed.*

Picture 88: Fixing upper lining.

Picture 89**:** Fitting the bass bar onto the finished top.

Picture 87: Fixing upper lining.

Picture 88: Top and body.

Picture 89: Top glued on.

Insertion of the purfling

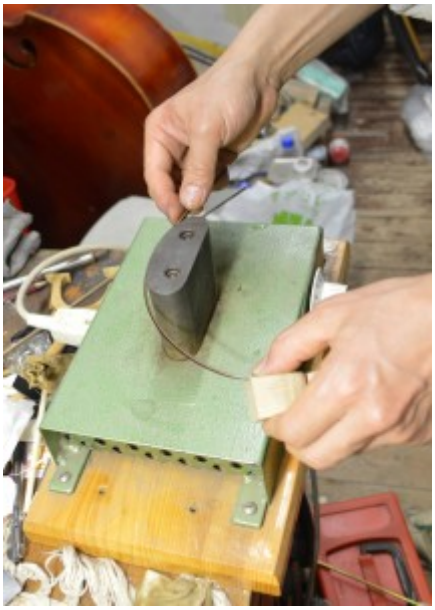
(For a definition of 'purfling' see Glossary.)

First a purfling cutter is used to sketch the precise outline of the purfling.

Picture 90: A purfling groove cutter.

Following the sketched line the wood is then being carved-out and the purfling strip is bend to match the outline.

Picture 91: Bending of a purfling stripe.



Picture 92: C-bout purfling put into place.

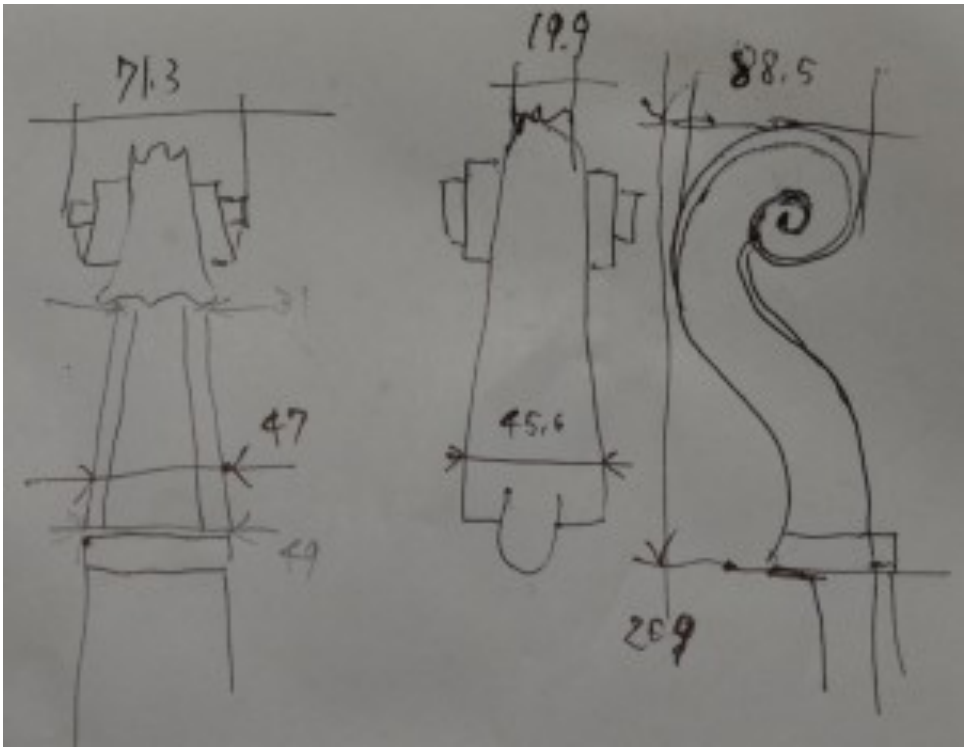
Picture 93: Finished purfling.

CONSTRUCTION V / Neck; Varnish; Bridge; Tailpiece

Construction of the neck

(**Note:** *From this point on the construction-process differs from the construction-process of a four string cello*.)

***Picture 91*:** Measurements of the scroll. (Sketch by Ueda).



Picture 92 and 93: *First states of producing the neck.*

Picture 94: Fingerboard attached.

In order to accommodate for the fifth string the fingerboard was made about 1 cm broader than a four string cello's. Accordingly the size of peg box and scroll is slightly larger than a four string instrument's.

Attaching the neck

***Picture 95*:** Provisionally attached neck.

***Picture 96*:** Attached neck.

Varnishing

Before beginning with the actual varnishing Ueda applied a solution made out of water and instant coffee. This resulted in a moderately dark foundation for the varnish.

Picture 97: Body stained with coffee solution.

There are countless possible combinations of ingredients to produce certain colors and qualities of varnish. The picture below shows the ingredients that Ueda chose for the final instrument.

Picture 98: Varnish material. From upper left to lower right: fish oil, elemy, shellack, copal. mastic, dragon's blood. (*See Glossary.)*

Picture 99: Front after third layer of front varnish.

Picture 100: Back after third layer of front varnish.

Construction of the bridge

The bridge has basically the same size and shape as a four string bridge. Only the head is somewhat broader in order to accommodate for the additional string. The distance between the strings is slightly smaller than on a four string bridge-otherwise the proportions between feet and head would become distorted.

Picture 101: Template of the bridge.

Picture 102: The finished bridge.

SPECIAL EVENT III

HANDING OVER PROTOTYPE II TO THE MUSASHINO INSTRUMENT MUSEUM

After the construction of the final instrument was basically finished (at this point of time only the fine-adjusters were still provisional and will be replaced by lighter models) Prototype II was presented to the Musashino Museum on October 20th 2015. It now can be checked out and used by interested students.

The head of the Musashino museum and library department, Prof. S. Shigematsu, and C. Doll at the Musashino museum in Iruma on the day of presentation.

(Picture: A. IGUCHI)

Construction of the tailpiece:

For the construction of the tailpiece Ueda chose a piece of rosewood. As mentioned before both Prototypes were equipped with fine-tuning pegs which proved to be quite practical. But because of the internal gears they are about 1/3 heavier than regular wooden pegs and Ueda was afraid that this fact would have a considerable, negative influence on the volume of the final instrument. It was therefore resolved to install custom-made light-weight adjusters on the tailpiece.

Picture 103: Tailpiece material and template.

Picture 104: Sketch of the tailpiece compared to a four string tailpiece.

Picture 105 and 106: The parts of the tailpiece and the partially assembled final tailpiece

THE FINAL INSTRUMENT

By February 15th 2016 the final cello was completed.

Picture 107: Final cello; front view.

Picture 108: Final cello; side view.

Picture 109: Final cello; back view.

IV. FINAL TESTS AND CONCLUSIONS

- **FINAL CONCLUSIONS ABOUT THE GENERAL USE AND FUTURE OF THE FIVE STRING CELLO**

NOVEMBER 2015

After playing the new cello for about one month it became obvious that the instrument basically suffers from the same impediments as both prototypes: While it has overall a much better sound quality there is a noticeable loss of volume on the higher registers of the G- and D-string compared to a four string cello. The quality and volume of the E-string improved to a considerable degree but the nasal character is still clearly noticeable. The A-string's sound is slightly smaller than a four string cello's and has also to some degree a nasal character.

JANUARY 2016

After having tested the prototypes and having played the final instrument for some months several conclusions could be drawn:

ACOUSTIC OBSERVATIONS

- All of the three instruments have a nasal sound character on the upper strings, especially on the E-string. The final cello has by far the best sound properties, the mentioned nasal character however basically remains the same. Overall the general volume of the instruments is smaller than a four string cello's.
- All of the three instruments have acoustic problems in the higher positions of G- and D-strings, resulting in volume loss and numerous wolf notes. Again, the final instrument has the best sound properties but shows the same acoustic problems, however to a smaller degree.

Basically, especially considering the high strings, even a master-made five string cello seems to end up with a sound character closer to a viol's than a four string cello's. The low strings' sound is closer to a four string cello's but lacks quality to some degree, especially in the higher positions.

TECHNICAL PERFORMANCE AND STILISTIC OBSERVATIONS

- When playing pieces intended for a five string instrument *(For a list of pieces for which the use of a five string cello could be appropriate see Appendix D.)* the advantage of using a five string cello is undeniable. As shown in detail in the next paragraph the presence of the fifth string facilitates playing such pieces to a tremendous degree compared to playing them on a four string cello. While the use of a four string cello requires the frequent use of very high and unnatural positions almost all high passages can be played in convenient positions on the E-string of a five string cello. (*Exceptions are pieces that were composed for significantly smaller instruments, such as the Suite BWV 101 and the Arpeggione Sonata. In those pieces sometimes still the use of the thumb is necessary and high positions even on the E-string cannot be avoided.*)

  Stylistically there is no problem whatsoever when performing pieces for five string instruments on a five string cello: Most of the available music is composed for some instrument of the viol family, which members all have a sound very similar to the instruments of this project. *(The arpeggione was a rather small instrument in guitar tuning. There are very few originals left, usually not available for playing, but modern replicas also sound very similar to viols. The BWV 1012 might be an exception: The replicas of the instrument it most likely was intended for (viola da spalla) sound more like a viola than a viol.)* The fifth string allows a performance in adequate tempos while using a four string cello often forces to compromises on account of frequent and big shifts.

- When playing pieces composed for a four string cello the use of a fife string cello proved to be less helpful than expected: When playing Baroque sonatas that were obviously intended for a four string instrument the E-string does not help much because high positions are very rarely used: Usually their tonal range does not exceed the fourth position on the A-string. (*The nasal sound quality does not really present any stylistic problems with these kinds of pieces; neither does the lack of volume since they were not written for performances in big halls.*)

  When playing classical or romantic pieces on a five string cello several problems became obvious: Because

the E-string string allows the use of lower positions where a four string cello player has to use high thumb positions the shifting system becomes completely different. The traditional education of a four string cellist becomes almost useless. All fingerings of etudes, sonatas and concertos would have to be re-written and practiced anew. The same is true for the entire orchestra literature. A four string cellist, willing to change permanently to a five string cello and using it for pieces of all époques would have to 're-learn' quite a big part of his technique. He also would probably have to quit using a four string cello altogether because the newly acquired technique wouldn't apply to a four string cello anymore..

Stylistically there are two major problems when using a five string cello for playing classical and romantic pieces that were composed for four string cellos: The viol-like sound quality and the loss of overall volume. Those two factors weigh rather heavily against the use of a five string cello in general use for this kind of music. When using five string celli in a symphony orchestra the sound quality of the section would be very different from the rest of the strings. The smaller sound also would probably require a bigger section size. As for solo- and chamber music: modern halls are quite big and the public taste nowadays usually connects viol-like sound quality to Renaissance- and Baroque music.

FINAL CONCLUSIONS ABOUT THE PERMANENT USE OF A FIVE STRING CELLO

As a solo or orchestra instrument the five string cello is not likely to replace the four string cello. The main reasons for this are the loss of overall sound volume, the difference of sound quality and the different shifting patterns. The latter factor could be overcome through intensive practicing in order to rebuild the traditional shifting system in the high registers. However this effort would be a waste of time when the instrument would be intended to be used for performing classical and romantic music: a five string cello's sound property compares unfavorably to a four string's when approaching this kind of music; it cannot really successfully compete with a quality four string cello. *(However, the four string cello as an instrument to perform the BWV 1012 will probably be slowly replaced by viola da spallas of various types.)*

The circumstances change completely when approaching works composed for five string instruments. The problem with different shifting patterns becomes non-existent because the fifth string was taken into consideration from the beginning of the creation of those pieces. They mostly were written for viols (*usually equipped with six strings, tuned in fourths and thirds*), not for a fifth-tuned five string cello, but this point is almost of no relevance since the tonal range is basically the same. With the exception of Bach's Suite BWV 1012 and Schubert's Arpeggione Sonata (*Both pieces were presumably written for small, arm-held instruments.*) such pieces can be throughout performed in comfortable positions - the use of the thumb positions is not necessary, which coincides with the fact that thumb positions were and are not used with viols. A new and rather big repertoire opens itself for the user of a five string cello that is usually not approached by four string cellists because of the extreme technical problems.

As mentioned before there are no stylistic problems with performing viol pieces on a five string cello: the sound properties are very similar and the pieces, ideally performed with the accompaniment of a cembalo, can be performed in a small hall as they were intended to.

The performance of Bach's BWV 1012 and Schubert's Arpeggione Sonata will be considerably easier when using a five string cello. This fact would make a five string cello the best choice for a cellist used to the Stradivari-size cello. . However, there still remain some technical difficulties that would not occur when the pieces would be performed on the original instruments.

- **The ultimate conclusion reached by this project is the fact that even a high-level five string cello is not likely to replace the four string cello and that the development of the four string cello as the dominant cello type was justified.**

  However, it is highly recommendable to use a five string cello for pieces that are written originally for five stringed instruments since it allows a natural and stylistically correct performance of such pieces. Owning a five string cello makes a wealth of beautiful pieces available that, if at all, are usually only touched by viol players.

  However, it is not to be expected that after reading this study many cellists will invest in a new, master-made five string cello. This probably means that in the future the count of Stradivari-type five string cellos will not dramatically change.

  For cellists who cannot afford to have a master instrument built there are still the possibilities to have a cheap four string cello turned into a five string instrument (*like the two prototypes of this project*) or equip a four string cello with the strings e',a,d,G and transpose the notes on the missing C-string one octave higher.

  It is not recommended to change a valuable four string cello to a five string cello because there are major quality changes to expect.

- **Since this project has led to a clear conclusion we consider it a success and are convinced that it will be helpful for many cellists who have engaged themselves in the matter of five stringed instruments.**

We want to express our sincere thanks to the Japan Society for the Promotion of Science for financing this project, to Kazuhiro Kaneko for his help with many difficult bureaucratic procedures, to Yoshio Ueda for his meticulous work, to Noburo Morishige for his kind help with many photographs and to Ayumi Kimura for the assistance with homepage and computer.

The following paragraphs describe the use of a five string cello with pieces for which the use of such an instrument might be helpful.

General tips for playing a five string cello

- Probably the biggest problem when playing a five string cello is to change strings by crossing over one or more other strings. Especially in the first weeks, even months often the D- and G-String will be mixed up, by the right as well as the left hand. One method to avoid such misses is to try to place the left hand before the bow on the string that has to be changed to. This helps the right hand to some extent to 'find' the string. Another method is to memorize the relevant places and actually look right at the string shortly before the change. If a string change leads back to a previously used string it helps to keep the finger(s) there during the change, even if actually a different finger or position will be used.
- Another problem is the fact that usually on a five string cello the strings are a little closer to each other than on a four sting cello. (*This is because the bridge would become too massive if a four string cello's measures would be kept.*) This might sometimes result in the bow's accidental touching of other strings. It is therefore recommended to play generally quite close to the bridge and keep the bow always in the optimal level.

- Generally the use of 'long strings' (low positions) is advisable when playing Baroque pieces. The unfavorable properties of a five string cello's 3rd and 4th positions make this an absolute must: whenever possible the low positions should be used.
- As mentioned above it is recommended to use a five string cello for pieces that were written for five string instruments. This makes pieces for viol the obvious choice. In spite of the fact that there are nowadays rather few viol players quite a lot of pieces are still available, on the internet as well as in commercial editions. (*If you contact us we can tell you about recommendable publishers.*)
- The E string should be wiped frequently because even a small amount of resin stuck to it affects the sound quality negatively.

● Playing the Suite BWV 1012 on a 7/8 Stradivari-Type Five String Cello

After completing two prototypes and deciding about fingerings and bowings, many hours of practicing lead to several conclusions about the question what kind of instrument the suite was originally composed for.

Since there is no doubt that the suite was written for a five string instrument those conclusions were based on the answer to the question if it is possible to conveniently render the full text of the suite BWV1012 on a five string Stradivari-size cello as opposed to a smaller instrument. A very important aspect for arriving at a correct answer is the fact that the use of the thumb was not yet introduced at Bach's time as a technique of playing the cello.

Another important point is the fact that in the baroque era there have been other, smaller cello types, equipped with up to six strings, most of them chin/arm-held.

Prélude

Points suggesting that the suite should be performed on a five string instrument:

Bach used in his cello suites frequently the technique of *Bariolage* *(See glossary.)* This technique involves the use of an open string for an accompaniment which separates itself from the melodic progression on another string *(See also Suite 1006; Prélude; M.33 and following.)* It is crucial that the separate notes are played on the different, open string; otherwise the melody cannot be properly recognized. Using a five string cello in the suite 1012 all bariolages can be realized as intended.

The long sixteenth passage starting in M.85 can be played in one single position on a five string instrument.

M.102 can be played without using the thumb.

Highest note on a five string Stradivari-type cello is the g'' in the 8th position of the E-string (M.74).

Points suggesting that the suite should be performed on a small, possibly chin/arm-held instrument:

One place suggests the use of the thumb (MM.21/22) and one place requires the use of the thumb (MM.70-76). Since the thumb was not yet used as a playing finger when the work was composed, it is safe to assume that the work was written for a much smaller instrument. (Other places within the six suites, for example the Menuet I of the Suite 1008 and the Préludes of the Suites 1009 and 1010, which request the use of the thumb, require unusually frequent shifts or extreme stretches, even when using a five string cello, indicate that all the suites were composed for a rather small instrument.)

Allemande

Points suggesting that the suite should be performed on a five string instrument:

The Allemande not once requires the use of the thumb or unusual amounts or types of shifts when executed on a five string instrument. The whole movement can be performed quite comfortably within the lower four positions on a five string Stradivari-size cello.

The Allemande resembles many movements of the violin sonatas and partitas in its intricate beauty which will be lost if performed on a four string cello.

Highest note on a five string Stradivari-type cello is the d'' in the 4th position of the E-string (M.3).

Points suggesting that the suite should be performed on a small, possibly chin/arm-held instrument:

There are no major points concerning this movement. Some small shifts could be saved but once getting used to the additional string any serious four string cello player could play this movement quite soon beautifully on a five string cello.

Courante

Points suggesting that the suite should be performed on a five string instrument:

The Courante also does not require the use of the thumb if played on a five string cello.

On a four string cello the execution of the Courante requires a number of shifts to very high positions. Those shifts turn on a five string cello mostly into string changes which can be mastered much more easily.

Highest note on a five string Stradivari-type cello is the b' in the 2nd position of the E-string (MM.3/26/40).

Points suggesting that the suite should be performed on a small, possibly chin/arm-held instrument:

As with the Allemande there are no major reasons not to perform the Courante adequately on a five string Stradivari-sized cello.

Sarabande

Points suggesting that the suite should be performed on a five string instrument:

The Sarabande is one of the most difficult movements within the suite(s) to be performed on a four string cello. Many of the chords have to be split into different positions, such disturbing a melodious performance. Generally a quite unique technical approach becomes necessary, very unusual even when using common modern cello techniques-techniques yet unknown to cellists of the baroque era.

The Sarabande of the Suite BWV 1012 presents cellists with tremendous technical problems, some of them unsolvable when using a four string instrument; a fact that certainly suggests that it should be performed on an instrument equipped with five strings.

Highest note on a five string Stradivari-type cello is the c'' in the 3rd position of the E-string (MM.13/14).

Points suggesting that the suite should be performed on a small, possibly chin/arm-held instrument:

Most of the chords can be performed in low positions on a five string Stradivari-cello.

The Sarabande can be properly performed with some minor difficulties on a five string Stradivari-sized cello, but it could be performed more easily on a smaller five string instrument: There is one place which requires changing positions within one single double stop (M.6; half position to 2nd position). That is not a technique used by cellists of the baroque era. The use of a smaller five string instrument would eliminate that problem.

Gavotte I

Points suggesting that the suite should be performed on a five string instrument:

All chords can be performed in the first four positions; the use of the thumb is not necessary.

Highest note on a five string Stradivari-type cello is the b' in the 2nd position of the E-string (MM.3/10/23/26).

Points suggesting that the suite should be performed on a small, possibly chin/arm-held instrument:

There is one place which requires changing positions within one single double stop (M.17; half position to 1st position). The chord requires either a shift or some unusual stretching; both are techniques that were not commonly used in the baroque era.

Gavotte II

Points suggesting that the suite should be performed on a five string instrument:

The piece can be performed throughout in conveniently low positions, which guarantee optimal acoustic conditions.

Highest note on a five string Stradivari-type cello is the a' in the 5th position of the A-string (MM.14/18).

Points suggesting that the suite should be performed on a small, possibly chin/arm-held instrument:

Playing this Gavotte on a smaller, chin-held instrument would not result in a significant advantage.

Gigue

Points suggesting that the suite should be performed on a five string instrument:

Using a five string cello most of the frequent shifts that are necessary on a four string cello become string changes, which are much easier to be mastered. (*This can be done by looking at the bow and the relevant string; a technique that is not necessary using a four string cello. On a five string cello correctly locating the lower three strings is rather difficult.*)

Highest note on a five string Stradivari-type cello is the d'' in the 4th position of the E-string (M.51).

Points suggesting that the suite should be performed on a small, possibly chin/arm-held instrument:

There is one place which requires the use of the thumb or some unusual stretching. (M.65; 4th to 3rd position) As mentioned before, those are techniques not commonly used in the baroque era.

CONCLUSIONS CONCERNING BWV 1012

Using a four string cello for playing the suite BWV 1012 presents a modern cellist with many technical and musical problems that are highly untypical for the baroque period. Those difficulties make a natural and correct performance problematic; even the most advanced players have to compromise – it is not possible to play the piece in its whole as it was composed.

Even when taking some possible sound loss into account the use of a Stradivari-type five string cello is the most recommendable way for cellists to approach the Suite BWV 1012. Especially smaller models, like the 7/8- sized instruments built during this project, seem to be most appropriate for such a purpose. There still are some few places where the use of modern techniques is necessary, but there would be no major compromises performing the suite by any professional cellist who is willing to invest a reasonable amount of practicing time.

The remaining crucial question is whether the possibly costly investment in purchasing such an instrument in order to perform one single piece of music is reasonable. Further research will strive to answer the question if there might be other compositions suggesting the use of a five string cello.

However, the ideal instrument for performing the Suite BWV 1012 would be a rather small, five string chin/arm-held instrument, used by viola players or violinists. In the recent past the most popular instrument of this kind became the Viola da Spalla as described by D. Badiarov. (http://badiarovviolins.com/PDF/GSJ60_121-145_Badiarov.pdf.)

(For a list of pieces for which the use of a five string cello could be appropriate see Appendix D.)

- **Playing the Sonatas BWV 1027-29 on a 7/8 Stradivari-Type Five String Cello**

Many musicologists now believe that those three Sonatas were originally written around 1720 as trio sonatas, and that Bach rewrote them in the 1730th for the viola da gamba *.(Viol.)* Lacking any cello sonatas from Bach's hand, cellists tend to play those pieces on their own instruments. However, a viola da gamba has six or seven strings and is tuned in fourths on the outer strings and in a third in the middle. Any attempt to perform a gamba piece on a four string cello will result in many technical and, therefore, musical problems. Generally to play Bach's works on different instruments than originally intended presents no stylistic problems as long as a natural performance is possible. It is a very difficult endeavor to do so using an instrument that has at least two strings less than the original instrument. Using a five string cello might not be an ideal solution, but the additional string could make a performance easier for cellists to a considerable extent – a bass viol (6-7 strings) has a tonal range from D to d', which is very similar to a five string cello's range. When playing the piece on a viola da gamba only low positions are being used throughout the entire piece. (*The highest frets of a viol are in an area that would be equivalent to the 3rd to 4th position on a cello.*) Played on a four string cello the piece frequently requires the use of the thumb, going up to the d" on the A-string. Often high positions on the D-string have to be used, registers that are not the most favorable ones on a cello, especially on cheaper instruments.

Sonata BWV 1027

(The Peters edition's measure numbers are consecutive for the movements I/II and III/IV since there is no solid double bar except at the end of the second movement and the fourth movement. Peters numbers are shown left of the slash. The numbers at the right of the slash are for the Henle edition which counts each movement separately)

I. Adagio:

This movement is not too difficult to be played on a four string cello. However, using a five string cello would save a lot of shifts and only request the use of the low four positions. The cellist can concentrate on the music without having to spend a lot of time practicing difficult shifts.

Highest note on a five string cello is the c" in the 3rd position on the E-string (M.20).

II. Allegro ma non tanto:

In this movement the first serious difficulties start when the piece is played on a four string cello.

- In M.40/12 using the thumb position with a rather awkward fingering is unavoidable. When using a five string cello this place can be played without any problems in the 1st position.
- M.67/39 requires either stretching or a very fast shift. Using a five string cello the open E-string can be used.
- M.73 /45 is identical to M.40/12 and the following two measures keep the player in a position using the thumb on a four string cello. Using a five string cello the whole passage can be played in the 1st position.
- M.86/58 and the following three measures force the four string player to use high thumb positions on the D-string or to perform some very difficult shifts on the A-string. On a five string cello the highest position of the passage is the 4th position on the E-string

Highest note on a five string cello is the d" in the 4th position on the E-string (MM.36/8 and 86/58).

III. Andante:

Like in the Adagio the use of a four string cello does not present major difficulties, but having a fifth string allows the use of lower positions throughout.

Highest note on a five string cello is the c" in the 3rd position on the E-string (M.1).

IV. Allegro moderato:

This movement presents major problems for four string cellists at two places:

- The shift from M.76/58 to M.77/59 into a thumb position. This shift becomes a string change on a five string cello, followed by a shift from the 1st to the 2nd position.
- The shift in M.133/115 into a thumb position. This shift becomes a shift into the 4th position on the E-string of a five string cello.

Highest note on a five string cello is the c" in the 4th position on the E-string (M.133/115).

Sonata BWV 1028

(The Peters edition's measure numbers are consecutive for the movements I/II since there is no solid double bar except at the end of the second movement. Peters numbers are shown left of the slash. The numbers at the right of the slash are for the Henle edition which counts each movement separately)

I. Adagio / II. Allegro / III. Andante:

Those three movements are not too difficult to play on a four string cello. However, using a five string cello would allow for a very comfortable playing in low positions with quite few shifts .

Adagio: Highest note on a five string cello is the a' in the 1st position on the E-string (MM.4 and 11).

Allegro: Highest note on a five string cello is the b' in the 3rd position on the E-string (M.77/54).

Andante: Highest note on a five string cello is the c' sharp in the 3rd position on the E-string (M.7).

IV. Allegro:

This movement is where a cellist would greatly appreciate the presence of a fifth string since it is rather difficult to play it on a four string cello.

- All sixteenth passages become quite easy to perform; for example the problematic first passage (MM.3 and 4) can be played in the 1st position having an additional string. On a four string cello either the use of the thumb or frequent shifting become necessary.
- The double stops in MM.75 - 78 don't require the use of the thumb and can be played quite easily in low positions.
- The measures 101 - 105 are on a four string cello rather difficult to play. On a five string cello the highest position is the third and the whole place does not present any serious problems.

Highest note on a five string cello is the c" in the 3rd position on the E-string (MM 25 and 102).

Sonata BWV 1029

Among the three Sonatas the BWV 1029 is the one where a fifth string would be the most helpful for any cellist since all three movements are quite difficult to be performed beautifully on a four string cello. When playing on a five string cello only the low four positions are used. The changes to the lower strings might be confusing at first but that problem that can be overcome after some smart practicing.

There a many places where the E-string saves from the use of awkward shifts and positions; the following mentions only the most prominent ones.

I.Vivace

- The rather difficult passage for four string cello players MM.22 and 23 can be played in the 1st and 2nd position on a five string cello.
- The parallel passage MM.57 and 58 can be played in the 3rd and 4th position on a five string cello.
- The big shifts in MM.70, 71 and 72 become manageable shifts in low position on a five string cello.
- The quite difficult passage for four string cellists MM.99 and 100 can be played easily in the 1st position on a five string cello.

Highest note on a five string cello is the d" in the 5th position[34] (*because of the trill the 4th cannot be used*) on the E-string (M.38).

II. Adagio:

- The far shift on a four string cello in M.10 to M.11 becomes an easy shift within the low four positions on a five string cello.

Highest note on a five string cello is the d" in the 4th position on the E-string (M.4).

III. Allegro:

- MM.37 and 38 require frequent shifting on a four string cello. On a five string cello both measures can be played in the first position.
- MM.57 and 58 are somewhat difficult to play on a four string cello. With a fifth string the passage can be executed in the first position.
- The final measures 108-111 require high positions on a four string cello. On a five string cello only the low four positions are used.

Highest note on a five string cello is the d" in the 4th position on the E-string (M.109).

CONCLUSIONS CONCERNING BWV 1027-29

Any cellist who has practiced the Sonatas on a four string cello and then tried them on a five string cello will be pleased how comfortably and naturally the pieces can be played. The E-string of a five string cello always will have a slightly nasal character but since the pieces were intended for a viola da gamba this does not present any stylistic problems.

After investing some practicing time getting used to the changes to the lower three strings it will be a pleasure to perform the sonatas an easy manor.

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34 This the only place in the three sonatas that goes beyond the low four positions.

Presumably four string cellists who have access to a high-quality five string cello will be thrilled to adequately perform those beautiful pieces on an instrument that is closely related to the one they were intended for.

(For a list of pieces for which the use of a five string cello could be appropriate see Appendix D.)

● Playing Schubert's Sonata D 821 ('Arpeggione') on a 7/8 Stradivari-Type Five String Cello

The arpeggione is a knee-held string instrument equipped with six strings in guitar-tuning. Its shape resembles both a cello and a viola da gamba. Its E-string's sound is quite different from a four string cello's relevant high positions' sound of the A-string, having a pronounced nasal, viol-like quality.

The arpeggione was introduced in the early 1820^{ies} and its popularity only lasted for about a decade. Nowadays the instrument is extremely scarce and the sonata Schubert wrote for it is mostly performed by cellists and viola players.

Playing the work on a four string cello puts extreme technical demands on the player – it is one of the most difficult pieces played on a Stradivari-type cello. Like on the guitar the highest string on an arpeggione is an E; the passages which were intended for that string force a four string cellist into very high positions on the A-string as well on the D-string.

Using a five string cello still presents many technical challenges, lacking one string, but the fact that its highest string also is an E –string might offer some facilitations.

I. Allegro moderato:

- The e" in M.17 becomes easily reachable from the G-sharp on the A-string.
- The f" in M.20 still needs a rather difficult shift on the E-string, the biggest problem being to avoid a portamento.
- When using the flageolet on the e" in MM.22/24 and 28 this passage becomes quite easy.
- From M.31-57 there is no use of the thumb necessary.
- The MM.60-62 still require quite high positions but are definitely easier to perform than on a four string cello.
- The far shift on a four string cello to e"-flat in M.67 becomes a shift to the 5th position.
- The a" in M.69 can quite easily reached by using the flageolet on the previous e".
- The chords in MM.71 and 72 are now in the 1st to 3rd position.
- The MM.74-157 can be played without using the thumb by cellists who can cover the octave in MM.102 and 104 using the first and fourth finger.
- MM.161-164 are still difficult but could be realized without major compromises after investing some practicing time.
- Until M.178-179 the use of the thumb is not necessary.
- After M.179 only MM.201-204 make the use of the thumb necessary.

II. Adagio:

(The measure numbers are consecutive for the movements II and III since the only double bar is at the end of the third movement.)

- With the exception of MM.30-32 the movement can be played in the low four positions until M.69.
- In M.70 the use of the thumb on the b' is recommendable.

III. Allegretto:

- Until M.216 there is no use of the thumb necessary.
- MM.212-218 could be played in low positions followed by a rather big shift on the in M.219. Another possibility would be to use in M.214 the second finger on the b' (A-string) and later change to the first finger somewhere in M.216.
- Proceeding until M.326 only the low five positions have to be used; use of the thumb is not necessary.
- The f"-sharp in M.326 can be reached relatively easily by using the second finger on the flageolet A one beat before.
- In the following measures (with the exception of M.346, the parallel place of M.316) only low positions can be used until M.414 where a shift into the 6^{th} position on the e" becomes necessary.
- With the exception of M.418 (parallel place to M.414) and MM.449-456 (parallel place to MM.212-219) low positions can be used until MM.496-510 and M.516-519; both of those places requiring the use of the thumb.

CONCLUSIONS CONCERNING D 821

Stylistically there shouldn't be any problems when performing the piece on a five string cello - the sound-quality of a high-level five string cello will possibly be quite similar, if not better, to the quality of an arpeggione, which sounds very much like a viola da gamba. Speaking from a strictly technical standpoint there is no doubt that the execution of the piece becomes easier when using an additional string. It still is a difficult piece but the fifth string allows more frequent uses of low positions and saves many difficult shifts.

The remaining crucial question is whether the possibly costly investment in purchasing such an instrument in order to perform one single piece of music is reasonable. Further research will strive to answer the question if there might be other compositions suggesting the use of a five string cello. *(For a list of pieces for which the use of a five string cello could be appropriate see Appendix D.)*

● Playing Luigi Boccherini's Cello Sonatas on a 7/8 Stradivari-Type Five String Cello

The Italian cellist and composer Luigi Boccherini (1743-1805) wrote almost thirty sonatas for cello and piano, of which the most famous ones are the six sonatas in A, C, G, E-flat, F and A, published most prominently in 1958/78 by G. Ricordi; Milano. There is little doubt that the sonatas were composed for a four string cello, but there are some aspects that could suggest the use of a five string cello: all the sonatas feature very high positions and can only be properly performed by highly skilled cellists who are willing to spend quite some practicing time on them.

While the pieces were composed in a period that is now generally called the classic period their style actually resembles more the so-called gallant style of the middle and late baroque period. This means that the powerful sound of a Stradivari type four string cello is not really necessary for an adequate performance.

Very few cellists immerse themselves in the cello sonatas, except occasionally in the 6th in A (*using the Ricordi edition's counting order*), mostly because it is sometimes a required piece at cello competitions. Since the sonatas are actually quite charming compositions it is a considerable waste to ignore them as a part of the study repertoire especially of young and amateur cellists. It is worth to examine if a five string cello would allow an easier access to those pieces.

Playing Luigi Boccherini's Cello Sonata Nr.1 a-major on a 7/8 Stradivari-Type Five String Cello

I. Allegro moderato:

- The first time the use of the thumb becomes necessary in MM.11 and 12 in order to play the grace notes.
- The following measures continue to require thumb positions until one measure before the repeat.
- Until M.37 the presence of the E-string only allows for minor facilitations.
- MM.37-40 can be played in the 1st position.

Highest note on a five string cello is the b'' in the 9th position

II. Largo:

- From the upbeat of MM.8 until M.14 comfortable, low positions can be used. (Cellists with small hands might have to use the thumb in M.10.)
- In MM.21, 22 and the first half of M.23 low thumb positions can be used.
- The rest of the movement can be played within the low four positions.

Highest note on a five string cello is the e'' in the 5th position on the E-string (MM.22 and 23).

III. Allegro:

- MM.7-11 can be played in 1st and 2nd positions.
- MM.17-21 and MM.17-34 can be played comfortably in low thumb positions.
- From M.79 until the end of the movement only the lower four positions have to be used.

Highest note on a five string cello is the e'' in the 5th position on the E-string (MM.18/20/22 and the following parallel passage).

Playing Luigi Boccherini's Cello Sonata Nr.2 c-major on a 7/8 Stradivari-Type Five String Cello

I. Allegro:

- When using a four string cello in M.27 the use of the thumb becomes necessary; on a five string cello 1st and 2nd positions could be used. M.7-11 can be played in 1st and 2nd positions.
- The highest position on a four string cello is the 7th in M.10 which would become a 3rd position on a five string cello.

Highest note on a five string cello is the c'' in the 3rd position on the E-string (MM.10 and 13).

II Largo:

- When using a five string cello thumb positions can be avoided in the entire movement.

Highest note on a five string cello is the d'' in the 4th position on the E-string (M.29).

III Allegro:

- Both on a four- and five string cello the use of a thumb position is not necessary until M.37.
- From M.37 to M.55 playing a four string cello requires the use of high thumb positions on A- and D-string. On a five string cello the passage can be executed in positions where the thumb can stay in the 7th position.
- Until M.111 there is no need for thumb positions on both types of cellos.
- From M.111 the use of a five string cello allows the use of a low thumb position without requiring any shifts.

Highest note on a five string cello is the a'' in the 7th (8th) when shifting) position on the E-string (MM.38/41/45/48/53).

Playing Luigi Boccherini's Cello Sonata Nr.3 g-major on a 7/8 Stradivari-Type Five String Cello

I. Largo:

- Until M.17 this movement is not too difficult on a four string cello but when using a five string cello the highest position until there would be only the 5th in M.13.

- On the upbeat to M.17 on both cello types the thumb has to be used. On a four string cello this passage requires the use of positions up to the a'' in measure 18 while on a five string cello the whole place until M.20 can be played in the 7th and 8th position.
- The cadenza in M.20 can be played in the 8th position (stretching the 3rd finger) on A- and E-string when using a five string cello.

Highest note on a five string cello is the stretched b'' in the 8th position on the E-string (M.20).

II. Allegro:

- When using a four string cello there is only in M.64 the use of high positions necessary.
- On a five string cello the whole movement can be played without using any thumb positions.

Highest note on a five string cello is the g'' in the 7th position on the E-string (M.64).

III.Minuetto:

- Only in MM.56-58 the E-string facilitates playing the movement; otherwise for both types using the same fingerings is advisable.

Highest position on the E-string of a five string cello is the 1st position in MM.56-58.

Playing Luigi Boccherini's Cello Sonata Nr.6 a-major on a 7/8 Stradivari-Type Five String Cello

I. Adagio:

- Until M.8 comfortable, low positions can be used.
- M.8 needs to use the 7th position and then leads to a rather comfortable thumb position in MM.9 and 10.
- M.11 can be played in low positions until from the upbeat to M.12 again the use of the thumb is suggested. If the high d-sharp'' in M.12 is played with the second finger on the A-string the following 64ths can be played in one position.
- From M.14 until M.20 the use of the thumb is not necessary.
- The 64ths passage in M.20, a rather difficult place when using a four string cello, can be played in one position on a five string cello.
- In M.21 one can either stay in the thumb position or play the double stops in low positions and shift after the fermata to thumb positions.

Highest note on a five string cello is the e''' in the 12th position on the E-string (M.22).

II. Allegro:

- Until upbeat to M.11 the E-string allows only for minor facilitations. In MM.11 to 14 the use of the thumb is necessary but in relatively comfortable low positions.
- In MM.19-25 the E-string becomes really helpful for the first time: the passage can be played until the first half of M.25 in the 1st position; MM.23-25 require only low positions (1st-2nd).
- Until M.52 the E-string again allows only for minor facilitations.
- MM.52-56 could be played on the E- and A-string but that would require a quite big stretch on the fourth beat of M.56, cellists with small hands might prefer using the A- and D-string.
- Because of the trills MM.57-64 probably should be played on the A-string.
- For the rest of the movement only low positions have to be used. The 16th in MM.71-75 can be played in the 1st position.

Highest note on a five string cello is the b'' in the 9th position on the E-string (M.57).

III. Affettuoso:

- In MM.5-7 instead of using a thumb position the open E-string allows for the use of the 1st position.
- M.12 can be played in the 1st position.
- MM.22-36 can be played rather comfortably in a low thumb position.
- MM.58 and 59 stay in neck positions.
- MM.65-72 can be played in the 1st position.
- In MM.73 the use of the open E-string allows for playing in 1st and 2nd position.

Highest note on a five string cello is the f-sharp'' in the 5th position on the E-string (MM.25/27/59).

CONCLUSIONS CONCERNING BOCCHERINI'S CELLO SONATAS

The sonatas frequently require the use of quite high positions, which is probably one reason why they generally are neglected by today's cellists (*with the exception of Nr.6 which is often a required piece in competitions*). Playing them on a five string cello is

not always easy but it would facilitate their performance to a considerable extent, a fact that might give them a higher, well deserved popularity.

From a stylistic standpoint there is no reason to oppose to the use of a five string cello, even when performing them in a concert. The only sacrifice for a possible loss of volume when using a five string cello would be having to choose a small hall.

(For a list of pieces for which the use of a five string cello could be appropriate see Appendix D.)

● Playing G. F. Händel's Gamba Sonatas on a 7/8 Stradivari-Type Five String Cello

An edition containing all twelve sonatas came out in the year 2015 by the German company Güntersberg / Heidelberg. The sonatas are documented by three sources (Kassel, London, Berlin); the Güntersberg edition is based on the Kassel source from the 18th Century.

The Kassel copy is in a very good condition but is lacking the name of the composer. In 2015 the Händel researcher Graham Pont came after handwriting comparisons to the conclusion that the Kassel copy was most likely produced by William Babell who was in the years 1711-1723 Händel's main copyist. Pont is convinced that the twelve sonatas are the work of the young Händel (1685-1759), composed before the year 1710.

It is probably not necessary to discuss all of the twelve sonatas in detail because they all have very similar structures and features: They have four movements with titles like Siciliana, Sarabande, Allegro, Adagio, Menuet, Affetuoso, Gigue and have an average length of about six minutes (repeats included). All sonatas except the Sonata 10 were in the Güntersberg edition transposed into keys that can be easily performed on a bass gamba. Those keys can also be comfortably realized on a five string cello. The Kassel manuscript has only a continuo bass line accompaniment without numerals. The Güntersberg edition provides a complete keyboard accompaniment.

● Tonal range of the Kassel sonatas:

Number 1 D-dur	Highest position on E-string: 4th position	Lowest string used: d
Number 2 a-moll	Highest position on E-string: 2nd position	Lowest string used: d
Number 3 D-dur	Highest position on E-string: 3rd position	Lowest string used: d
Number 4 G-dur	Highest position on E-string: 2nd position	Lowest string used: d
Number 5 D-dur	Highest position on E-string: 4th position	Lowest string used: a
Number 6 d-moll	Highest position on E-string: 6th position	Lowest string used: d
Number 7 D-dur	Highest position on E-string: 3rd position	Lowest string used: d

Number 8 G-dur	Highest position on E-string: 1st position	Lowest string used: G
Number 9 D-dur	Highest position on E-string: 3rd position	Lowest string used: d
Number 10 F-dur	Highest position on E-string: 4th position	Lowest string used: d
Number 11 D-dur	Highest position on E-string: 4th position	Lowest string used: d
Number 12 D-dur	Highest position on E-string: 2nd position	Lowest string used: d

GLOSSARY

adjusters the small screws on the tailpiece that are used for fine-tuning a string instrument

bariolage this technique involves the use of an open string for an accompaniment which separates itself from the melodic progression on another string; (See also Suite 1006; Prélude; M.33 and following.);it is crucial that the separate notes are played on the different, open string; otherwise the melody cannot be properly recognized; using a five string cello all bariolages in the suite 1012 can be realized as intended

bass bar a wooden beam glued roughly parallel to the strings onto the underside of the belly of a string instrument; its main function is, like the sound post's, to withstand the pressure from the strings; with the introduction of longer necks, steel strings and higher tuning pitches the bass bar gradually became thicker and longer

belly the top or lid of a string instrument

bridge one of the two places of a string instrument where the string's vibration is stopped down by touching a part of the instrument (the other one being the *nut*); it is positioned between the *F-holes* and transmits the vibrations of the strings to the belly and through the sound post to the bottom; see pictures 7, 11; there are two basic types of bridges: Belgian and French; Belgian bridges have long legs, a slight body and produce a strong and bright sound color. French bridges have shorter legs, a bigger body and produce a gentler and warmer sound color

bouts/ribs the side walls of a string instrument

button the top part of the back of a string instrument; it is a rather important part of the instrument: since the neck is glued-on there a considerable amount of pressure has to be accounted for

Button of a cello

c-bouts the c-shaped and mirror c-shaped narrowing of the body in the middle of a string instrument; the c-bouts are necessary to allow the bow access to the outer (C and a) strings; a further reason for the necessity of the c-bouts is the strong pressure on the belly in that area, the body has to be narrower there in order to deal with that pressure

A c-bout of a cello.

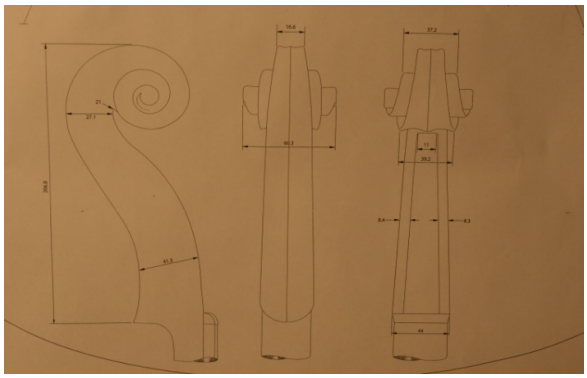
endpin the endpin is an extractable rod at the bottom of the cello; without it the player would have to clamp the instrument between the knees; endpins are produced in various types and materials but tests have shown that a cello produces the biggest sound when equipped with the massive steel type

f-holes the f-holes are the two f-shaped openings on the belly of a string instrument; the bridge transmits the strings' vibrations to the belly and the sound post transmits them to the bottom; the collected vibrations in the vessel are then reflected through the f-holes to the outside and reach the listener's ear; the f-shape was chosen rather for acoustic than decorative reasons

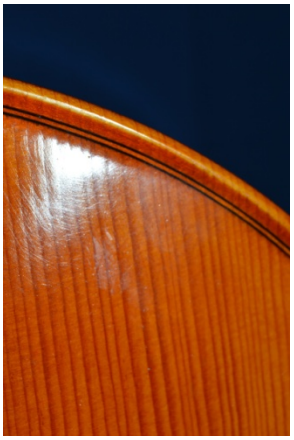
nut one of the two places of a string instrument where the string's vibration is stopped down by touching a part of the instrument (the other being the *bridge*); the nut is located just below the *peg box*; the distance from bridge to nut determines the *string length*; string length of a 4/4 cello is ideally between 680 and 690 mm

peg box the highest part of the neck of a string instrument containing the screw-like devices (pegs) that allow the crude tuning of the strings; the lowest part of the peg box is just above the *nut*; the highest part of the peg box is the *scroll*

Sketch of a cello's peg box. The top part is called the *scroll*.



purfling an inlaid strip with black edges, placed on the outer brim of the belly of a string instrument; purfling serves not only esthetical purposes but also is supposed to stop potential cracks proceeding along the graining lines of the wood



ribs/bouts the side walls of a string instrument

scroll the upper part of the peg box; its acoustical influence on an instrument's sound is disputed – the esthetical influence is not: the beauty of the scroll is another 'calling-card' of a *violin maker*

sound post a round stick, positioned inside the instrument slightly in front of the left foot of the bridge; it helps to withstand the pressure from the bridge and also transports the vibrations from strings and bridge to the bottom

string length the distance of the strings from *bridge* to *nut;* on a 4/4 cello ideally between 680 and 690 mm

tailpiece a piece of wood, metal or plastic that is fixed between the end pin socket and the lower ends of the strings; usually it is equipped with *adjusters*

violin dealer a person who sells string instruments but is not necessarily able to manufacture or to repair them

violin maker also called a luthier; a person who can manufacture and repair any string instrument, not only violins; not to be mistaken with a *violin dealer* a violin maker might sell instruments and instrument-related items but his priority is the conservation of existing instruments and the creation of his own; repairing and building string instruments requires a very high level of craftsmanship and knowledge in many different disciplines

wolf a disturbance of a string's vibration on certain pitches, caused by acoustical interferences between the vibrations of strings and the instrument's body, producing the so-called wolf-note; on a four-string cello it is usually most strongly present within the G-string's forth position, affecting pitches from e to g

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APPENDIX

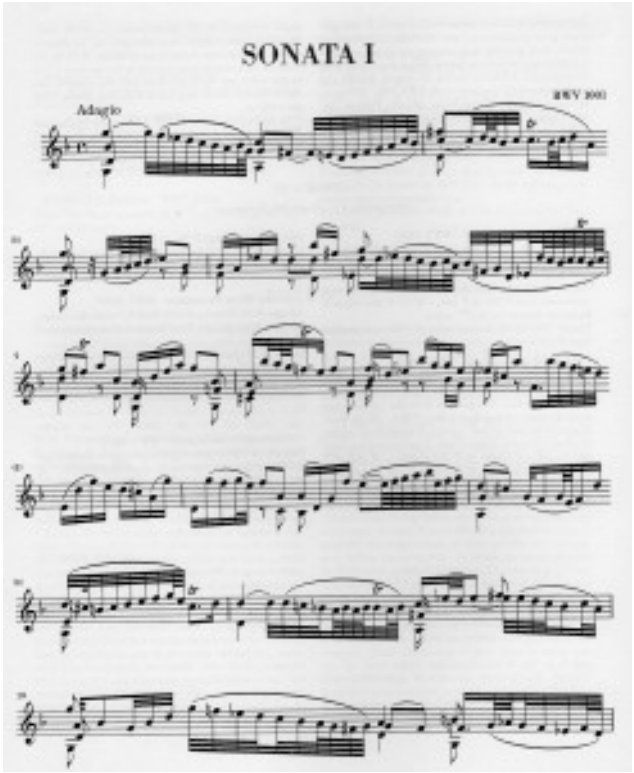
Apendix A:

C. Doll trying a newly-built violoncello piccolo at a String Fair in 2014.

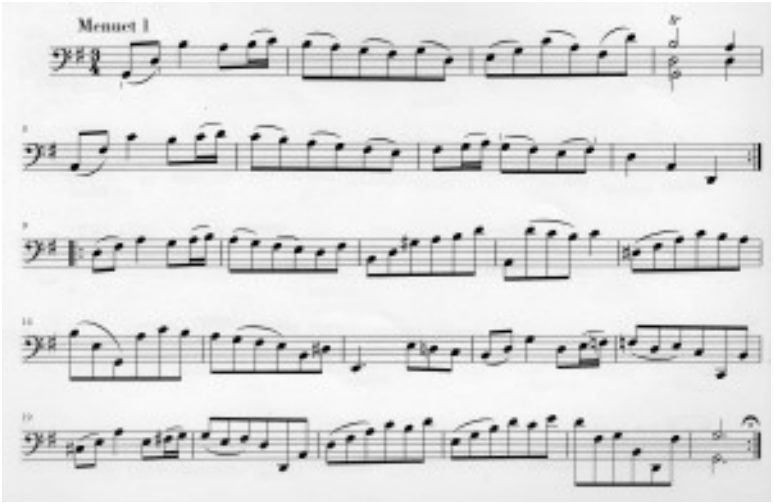
The size of this instrument is completely different from a 4/4 or a 7/8 cello. It is not impossible to be used by a cellist, but since it is so very small, it most likely needs a quite long period of practicing in order to adjust to its short string-length. *(For a better understanding of the instrument's size: Doll is 185cm [6'].)*

Appendix B:

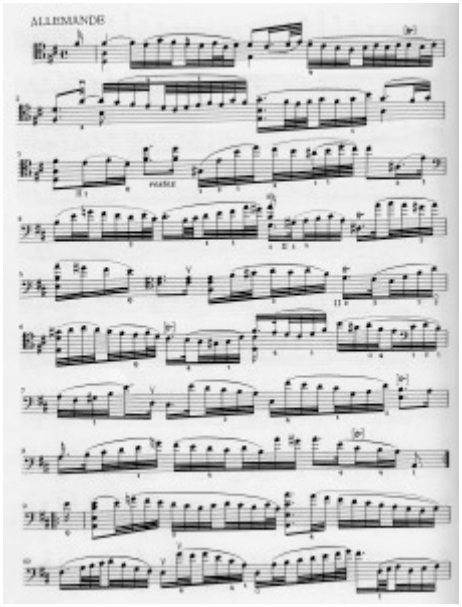
Beginning of the 1st movement of the 1st Violin Sonata BWV 1001:



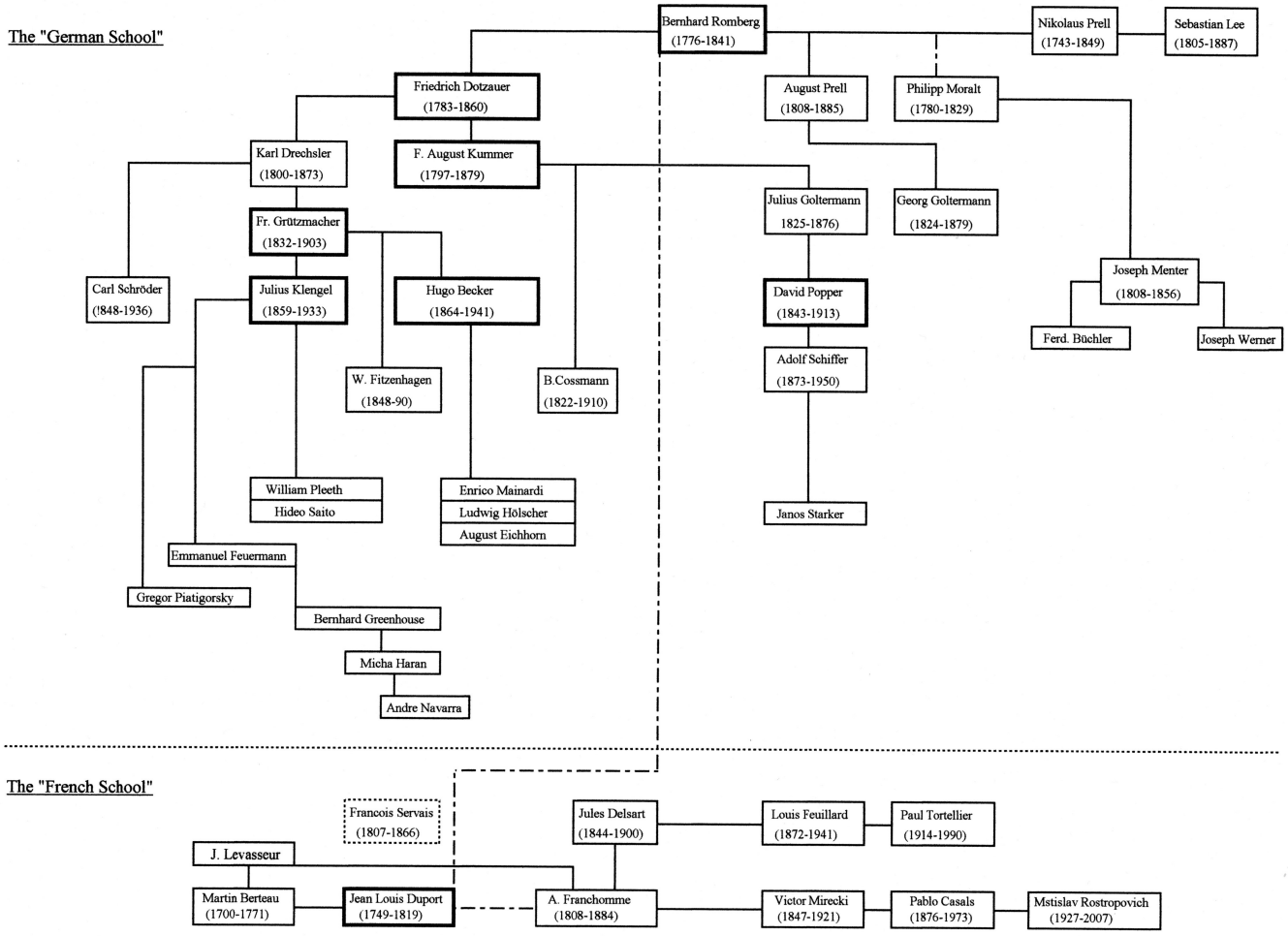
Menuet of the 1st Suite for Violoncello solo BWV 1006:



Beginning of the Allemande of the 6th Suite for Violoncello solo BWV 1012:



Appendix C:



Appendix D:

Pieces for which the use of a five string cello could be appropriate:

J.S. Bach:	Suite BWV 1012+
	Sonatas BWV 1027-19*
C.Ph.E. Bach:	Sonatas Wq 88*, 136*, 137*
J.Ch. Bach.	Sonatas Warb B 2b*, 4b*, 6b*, 15b*
L. Boccherini:	6 Sonatas (*Ricordi edition order*)
L. de Caix d'Hervelois:	Suite I* / Suite II*
F. Couperin:	La Bandoline*
A. Forqueray:	Suite Nr.I*
	La Gaillarde* *(Arr.: L. Feuillard)*
G.F. Händel: *(attributed)*	12 'Kassel' Sonatas“
A. Kühnel:	Partita XIV*
	Sonata A major*
M. Marais	L'agréable* / Le Provençale*
	Suite A major*
F. Schubert:	Sonata D 821#

*+Originally for a five string instrument. *Originally for Viola da gamba. #Originally for Arpeggione. “Originally for Viola da gamba or recorder.*

NOTE: With the exception of BWV 1012 all pieces above are with accompaniment.